Blackie's "TECHNIQUE" Series

TELEVISION

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PLATE I

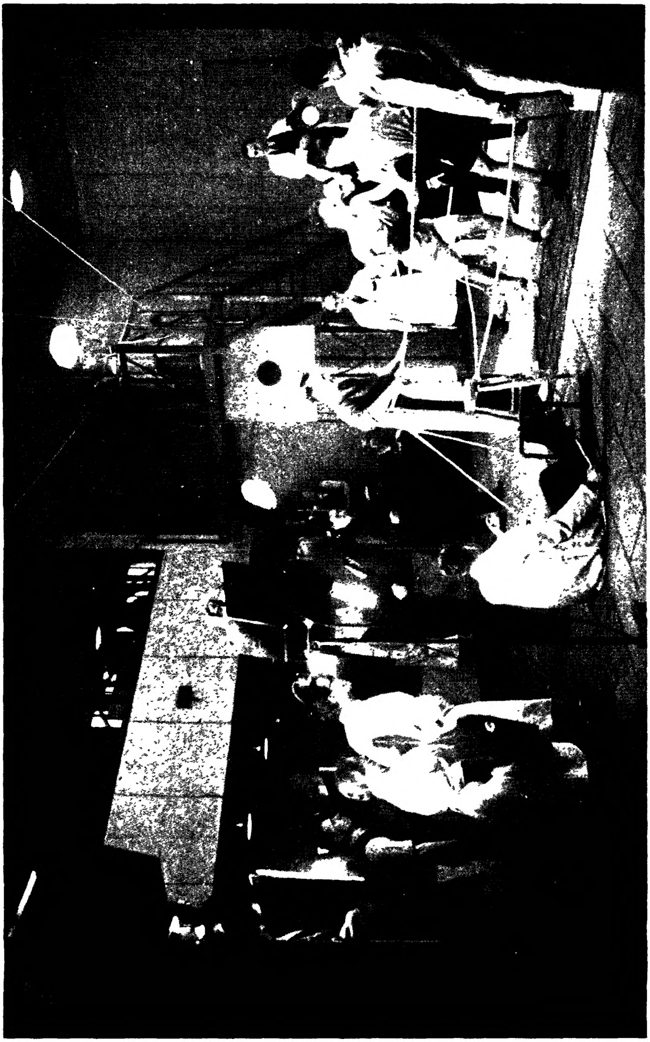

Photo courtesy of Baird Television Ltd

Boxing scene being transmitted from Studio by Intermediate Film Process

TELEVISION

BY

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PREFACE

A difficult task has been attempted in this book.

The non-technical public have seen television in the newspaper headlines, and want to know what it is all about and whether it is capable of providing good entertainment.

The wireless amateur who is already familiar with ordinary broadcasting wants to bring himself up to date in television, and to find out what scope it offers for experimental work on his own scale.

The aim has been a fairly comprehensive and unpadded survey of the subject for the latter, without being unintelligibly concentrated for the former; so that neither is the one exasperated nor the other bewildered.

The Report of the Selsdon Committee has given an official status to television, and at the same time has changed its outlook. It is on this basis that the book has been written.

The author's thanks are due to the B.B.C. and the various television firms who have supplied illustrations and information.

M. G. S.

BROMLEY, KENT,
May, 1935.

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TELEVISION

CHAPTER I

What Television Involves

Sound and Sight.

The cinema entertained the world with sight alone for about 25 years before adding sound to complete the picture. When it came, it came quite suddenly. Radio broadcasting started with sound, and is still moving gradually towards the combination with vision. The root difference between it and the cinema is that the moving picture is transmitted from a distance; hence *tele*-vision. For this reason the picture is not confined to scenes " bottled up " on film; it may show events taking place at the same instant. In this respect it corresponds with the broadcasting of programmes in sound, which may come either indirectly from records or straight from the original event or performance.

Television must also be distinguished from picture telegraphy, which for some years has been a normal means of supplying newspaper illustrations quickly from a distance. It was even tried for a time by the B.B.C., but the pictures sent out did not prove to be worth the trouble and expense of the extra receiving apparatus. These still pictures can be transmitted at leisure, comparatively speaking; in practice a single picture may take as long as half an hour to complete. The most serious technical difficulties in television are due,

as will be shown later, to the necessity for completing an entire picture in a fraction of a second, in order to follow it by the next with sufficient rapidity to give the illusion of motion.

It is possible for the methods of picture telegraphy to be adopted to provide the appearance of television. There is the famous occasion when a short film of the arrival of Scott and Black was laboriously telegraphed from Australia to England. It took a few seconds to show, but nearly as long to send as the journey of the airmen. True television need not necessarily coincide in time with the actual event, any more than broadcasting a musical performance, which may be from a gramophone record made some time earlier. But the process must take no longer than the original event.

Experience with motion pictures has shown that not less than about 25 pictures should be projected on the screen per second, or the eye is conscious of flicker. In present-day practice the rate is still further increased by showing each picture more than once. So it is obvious that the methods of picture telegraphy, if they apply at all, must be speeded up very considerably for television.

How the Eye Works.

In the process of seeing a thing direct, the light from the object seen is focused by the eyeball on to the retina at its rear, in exactly the same manner as in a camera. The retina is a sensitive surface made up of innumerable tiny elements that are linked to the brain by nerves; and the brain is informed as to the outer world by the sensations transmitted along these nerves as a result of the light falling on their ends. The picture received by the brain is therefore a mosaic, built up of light and dark patches according to the messages transmitted by the nerves. Although there are a vast number of these nerves, so that one is not conscious of their individual contributions, yet there is a limit to the fineness of detail that can be perceived.

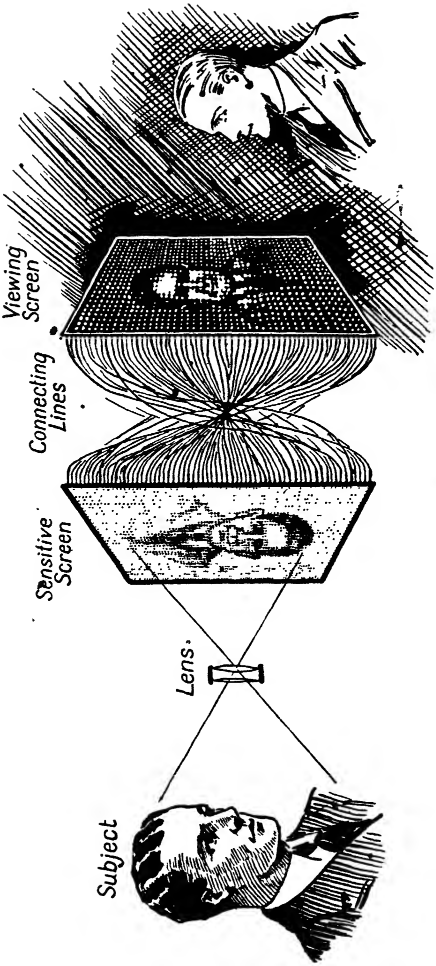

Viewing Screen
Connecting Lines
Sensitive Screen
Lens.
Subject

Fig. 1

Elementary Television.

Some of the earliest attempts at television were based on the same principle, by focusing an image of the subject on to a surface containing a large number of light-sensitive cells, each connected by wire to a controllable source of light on a similar surface at the receiving end, where the lights and shades were reproduced in the same proportion (fig. 1). This scheme at the best is very crude, because the number of nerve elements linking the eye to the brain can never be remotely approached by any reasonable number of lines linking the transmitter to the receiver. In fact, for practical purposes the number of lines (or radio channels) is restricted to one; which obviously rules this method out completely.

The three sisters of mythology, who had only one eye between them, had to get over this difficulty as best they could by passing on the single eye from one to another. The same course is followed in television. The individual picture elements at the transmitter are put in communication with the corresponding portions of the receiver screen in quick succession, and the signals indicate which portions are light and which are dark.

It is impossible to dictate over the telephone an entire page of a book simultaneously. But by taking the syllables one at a time, in an agreed order—which, however, differs according to whether the language is European, Hebrew, Japanese, &c.—the person at the transmitting end can get his hearer to reproduce a copy of the page.

Unless the sender announces the end of each line, and also the end of each page if there are a number of them, it is highly unlikely that the words will be distributed over the page at the receiving end in exactly the same way as in the original. That is not generally a matter of much importance in sending verbal messages, but it is absolutely vital in television. It would not be much good sending a priceless mosaic to the British Museum in the same way as a sack of potatoes. But the original picture could be reconstructed if the pieces

were posted one at a time, so long as they were delivered in the right order and put together according to a prearranged plan.

These are not merely fanciful illustrations; some years ago a portrait was dictated to B.B.C. listeners, who were told to type out certain letters and spaces in a given order. When viewed from a little distance the result—if done correctly—was an easily recognizable picture. This provides a perfect illustration of the process of transmitting a single picture by television; except, of course, as regards speed.

The Problem.

Now let us gather the essentials of the problem together. That there must be some means of causing light and shade at the transmitting end to control electrical signals, and vice versa at the receiving end, goes without saying. Assuming—as in practice one must—that only a single line of communication is allowed, by radio or otherwise, it is clear that the picture must be transmitted piecemeal. It is also essential that the receiver should reproduce the pieces in the right order and distribution. Finally, the whole process must be repeated many times per second.

Scanning.

The method of dealing with the picture in an agreed order is known as scanning, and generally follows much the same lines as the action of the eye in reading a book. Light from a small selected area of the subject is focused on a light-sensitive cell, which responds by giving rise to an electrical signal bearing some proportion to the intensity of the light received from that particular spot. The signal, being rather feeble, is amplified until it is capable of controlling the output of a broadcasting transmitter. The scanner continuously varies the position of the small area being " seen " at any one time, first along a line near one edge of the subject. When it reaches the end it is made (in most

systems) to send a special synchronizing signal to the receiver to announce that fact. It then starts again, but a little lower down; and in due course covers the whole area of the scene to be transmitted.

A second type of synchronizing signal may be sent at this point, so as to ensure that the receiver is made ready to start the next picture. Some scanners move in horizontal lines, like English print; and some vertically, like Japanese. Generally the direction of scanning is the longer dimension of the picture.

Meanwhile the signal which has been picked up at the other end, on a receiver differing only in detail from that used for the audible part of the programme, is being used to control the intensity of a spot of light, which is moved over a screen by the receiving scanner in exact time with the transmitting scanner. In this way the light and dark parts are reproduced in the same relative positions as those at the transmitting end. And it is all done so quickly that the eye cannot follow the motion, but owing to the "persistence of vision" gets the effect of a complete picture.

It is impracticable to ensure that the receiving scanner continues to run of its own accord at exactly the right speed without adjustment by the "televiewer"; hence the synchronizing signals are used at regular intervals to curb any tendency to drift; which would make the picture unsteady, or even dissolve into streaks.

The details of the apparatus needed to carry out these processes will form the subject of subsequent chapters. Meanwhile the reader who is familiar with the processes of broadcasting speech and music will have noticed that a large part of the system is the same, in principle at least. Instead of a microphone there is a light-sensitive cell or cells; and instead of a loud speaker there is a controlled source of light. Everything in between—amplifier, radio transmitter, radio receiver, and again an amplifier—is common to both sound and vision systems. In each case the impressions, whether

of sound or light, are transformed into corresponding electrical signals at the transmitter, and back again into sound or light at the receiver; the reason for this roundabout proceeding being that electrical waves have a greater range than sound or light, and possess the considerable extra advantages of being inaudible and invisible.

A Difficulty.

The electrical signals required to transmit sound correspond in frequency of alternation to the frequency of audible sound waves; which covers a band of about 30–15,000 cycles per second. Owing to the fact that the frequencies emitted by European broadcasting stations are spaced only 9000 c./s. apart, and that they necessarily " spread " each side to the extent of the highest audible frequency broadcast, the sounds transmitted are usually limited to about 8000 c./s. Even this causes a certain amount of overlapping and mutual interference, so in practice the majority of receivers exclude everything above 4000 or 5000 in the interests of selectivity, but with a corresponding sacrifice of tone quality.

In television the frequency of the electrical signals set up by the scene to be transmitted is determined by the number of alternations between light and darkness scanned per second. The maximum would be reached if every small area successively scanned—called a picture element—were alternately light and dark. *Two* successive picture elements would cause one complete up-and-down alternation; in other words, one cycle.

The picture plates in this book are each built up of 907,200 picture elements. If the whole thing were repeated 25 times per second, the signal frequency would be $\frac{907{,}200 \times 25}{2} =$ 11,340,000 c./s. or 11,340 kilocycles/sec. (kc./s.). As the whole band of frequencies available for broadcasting, on medium and long waves combined, amounts to only about 1100 kc./s., it is obviously impossible to accommodate even

a substantial fraction of one television station working on these assumptions!

Clearly the definition of the picture must be coarsened enormously before transmission can be considered on the same basis as for sound. The television transmissions which the B.B.C. has been sending out experimentally by the Baird system for a number of years are scanned in 30 lines vertically up a frame 7 in. by 3 in. There are therefore 70 picture elements per line, and the picture frequency is only $12\frac{1}{2}$ per second—a rate which is certainly less than ideal. So the signal frequency is $\frac{30 \times 70 \times 12\frac{1}{2}}{2} = 13{,}125$ c./s.

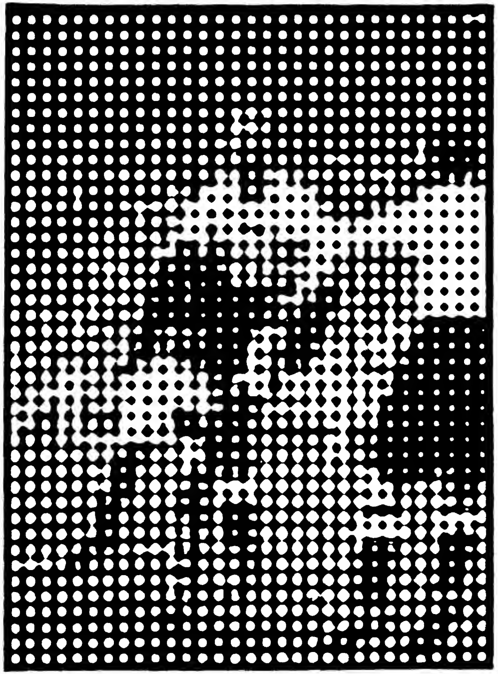
This is somewhat higher than the maximum put out by the audible programmes, but not impractically so. It is doubtful whether the very highest frequencies can actually be received under any but exceptional conditions, because the two other broadcasting stations adjacent in frequency are liable to cause interference unless relatively very weak. There is therefore a further loss in definition.

Picture Definition.

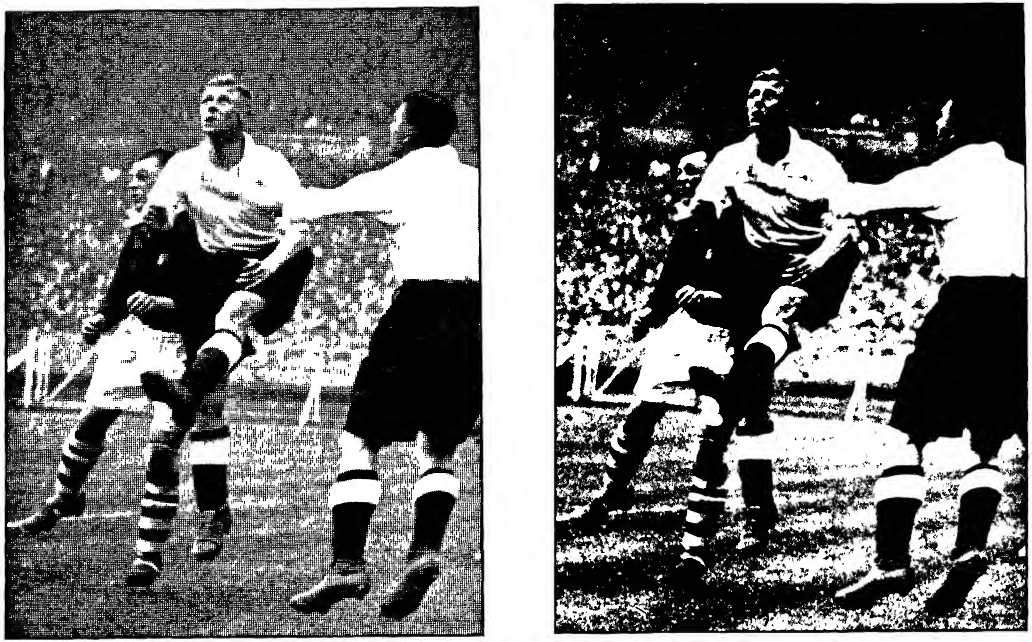
Plate II (A) shows the effect of reproducing a picture with approximately the same numbcr of elements as that just described. It is very coarse; but distance lends improvement. As it takes advantage of the full number of picture elements specified, and moreover has no "flicker", it might be thought to represent the absolute limit of what could be done with television of such low signal frequency. Fortunately, however, the effect of motion is of considerable benefit in improving the apparent definition.

It has an important bearing on television programmes that a degree of definition which is quite passable for head-and-shoulders views is more or less unintelligible when used for large spectacular scenes. Readers who would like to see the matter of definition dealt with more fully than space permits here are strongly advised to look up a paper by W. H. Wenstrom

F. 949


A


B



C D

A picture printed with various half-tone screens, to illustrate the comparative definition of (A) 30-line, (B) 180-line, (C) 240-line, and (D) 500-line Television

in the *Proceedings* of the Institute of Radio Engineers for September, 1933. An abstract, with some of the sample pictures, appears in *Television*, September, 1934, p. 387.

The picture reproduced on Plate II is one that is really outside the scope of low-definition television (as will readily be judged from sample A). With carefully chosen subjects, 30-line television can be made moderately recognizable. Even so, the Selsdon Television Committee very rightly pronounced that a service of this type would fail to secure the sustained interest of the public generally, however fascinating it may be to the experimenter.

Sample B shows the vast improvement when the number of lines is increased to 180, as standardized for use in Germany; C is with 240 lines; and D with 500 (which is beyond practicability at the present time, but may be reached in the future).

Mention must be made of an important point which often gives rise to confusion even in well-informed circles. The size of the reproduced picture does not affect the definition. It is necessary to view an enlarged image at a greater distance, but the amount of detail that can be perceived is the same. The definition provided by the cinema theatre is highly satisfactory, and is generally regarded as an ideal towards which television must aim. Yet when viewed a foot or two from the screen the picture appears coarser than the worst television. For this reason the standard defined by the number of scanning lines in television is a truer one than would be any standard such as is used for book illustrations, based on a number of elements per inch.

The Television Committee, after close investigation both in this country and abroad, advised that a public television service should be based on not less than 240 scanning lines and 25 pictures per second. Assuming a picture in the proportions 8 in. by 6 in., this means a minimum signal frequency of just below a million cycles per second. The only way to broadcast this is to use a wave-length of something

like 6 metres, corresponding to 50 million cycles per second, or 50 megacycles per second (50 mc./s.). The transmission then spreads between 50 ± 1 mc./s., say 49 to 51, which is only 2 per cent each side and therefore quite practicable. The Droitwich sound transmissions extend from 190 to 210 kc./s., which is 5 per cent each side. The maximum that is feasible is usually taken to be 10 per cent. The problems raised by this choice of wave-lengths, so remote from those of accepted broadcast practice, will be discussed in Chap. VI.

Apart from the mere width of the frequency band to be transmitted for television, the requirements may be expected to be considerably more stringent than they are for sound. Although it is not by any means strictly true that "seeing is believing", the eye is a good deal less easily fooled than the ear. Visible distortion is more noticeable than audible distortion, and this considerably affects the design of the broadcast part of the apparatus.

There are other difficulties in extending the technique of sound broadcasting to vision; they concern the television equipment more particularly, and this we now proceed to consider.

CHAPTER II

The Equipment

Importance of the System.

The details of the many television systems that have been devised are so multifarious that before plunging into them it will be helpful to take a general view of the parts that are necessary to constitute a complete system. Quoting from the Television Committee's Report: ". . . there will be little, if any, scope for television broadcasts unaccompanied by sound." It will be taken for granted that any installation for television includes provision for sound. In practice they may be dealt with entirely independently; but, as will be explained later, certain parts on the receiving side at least may conveniently be common to both " senses ".

The reader is assumed to have some acquaintance with the methods of broadcasting sound. In spite of all the tremendous changes and developments since the crude beginnings of a dozen years ago, it has never been absolutely obligatory to scrap any sort of receiver. An ancient crystal set may suffer by comparison with the latest superhet, but it has not suffered by any changes that have taken place in transmission methods since it was first used.

Secondly, a receiver that is used to listen to the B.B.C. transmissions is also suitable—given sufficient range—for transmission sent out by German, Russian, American, or Japanese organizations, each employing their own special types of equipment.

Neither of these conditions necessarily holds good with

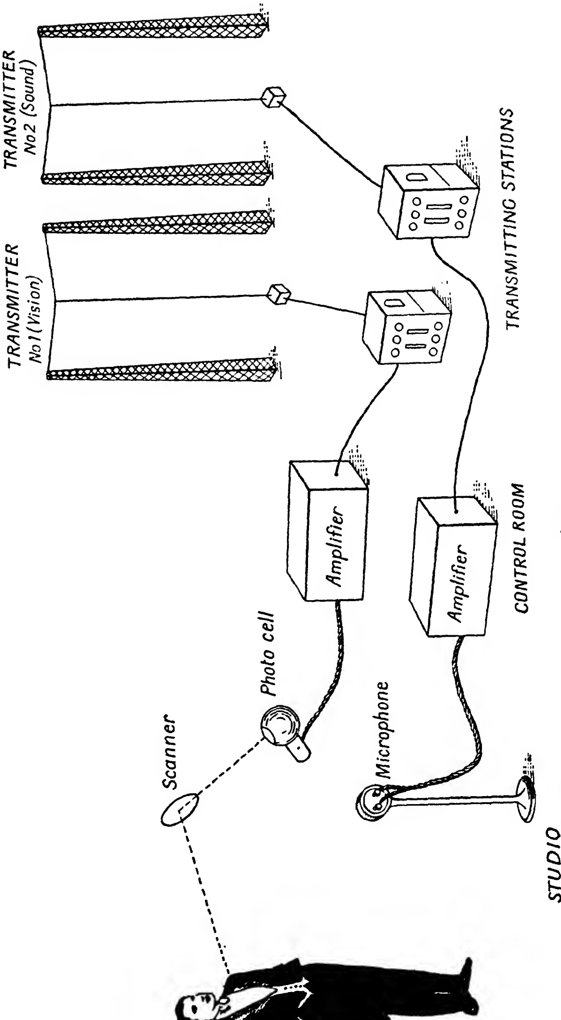

TRANSMITTER
No1 (Vision)
TRANSMITTER
No2 (Sound)
TRANSMITTING STATIONS
Amplifier
Amplifier
CONTROL ROOM
Photo cell
Scanner
Microphone
STUDIO

Fig. 2a

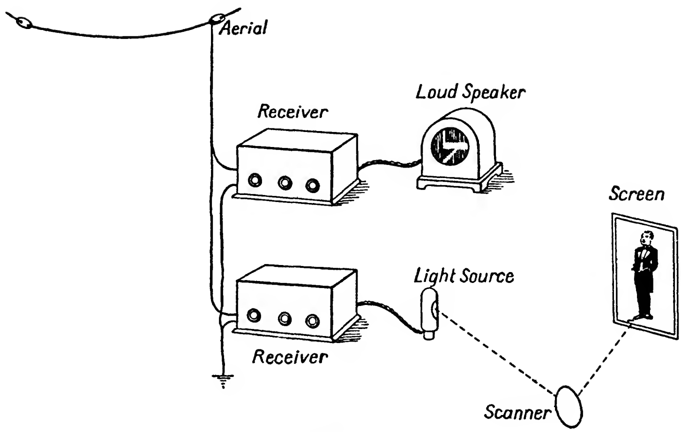


Fig. 2b

television. One of the things that have deterred even keen experimenters from setting up television receivers has been the consideration that the apparatus is linked to a particular system, and is liable to become entirely useless when the system is succeeded by something better, or when tuned to a transmitter of another type.

The Television Committee fully realized this difficulty and framed its recommendations with a view to giving some assurance that future improvements would not throw receivers out of use unless absolutely necessary in order to establish a definitely better service, and even then only after a period of years.

The low-definition television transmissions in this country were always on an openly experimental basis, and their abandonment carries with it most of the receiving apparatus that has been used. They have served an essential purpose as material for experimentally developing the art; in fact, experimenters will still be free to carry out their own transmissions and will probably continue to do so. Low-definition apparatus is given space even in this small volume, if only

as a stepping-stone towards explaining the more advanced systems that are required for high-definition public services.

The Transmitter.

A diagrammatic illustration of a complete sound and vision system, type unspecified, appears in fig. 2. The speech or music associated with the subject is picked up by a microphone, and the feeble electrical impulses set up thereby are strengthened and controlled by one or more amplifiers. The diagram gives no idea of the elaborate nature of the apparatus that may be used to amplify, control, measure, and distribute the " signal ". At a suitable level of strength it is passed along a line to the transmitting station, where it is used to modulate the output of a radio transmitter. This is the ordinary broadcasting system.

The television equipment in the studio, or in an adjoining room looking on to the studio through a window, consists of the scanner and a photo-cell. The scanner is shown in its simplest form—too simple to be practicable, actually—of a mirror vibrating rapidly to and fro and up and down so as to reflect the light from all parts of the subject in turn on the photo-cell. This is the equivalent of the microphone, and gives rise to electrical currents that depend on the amount of light received from moment to moment. In practice there are more or less complicated optical systems for focusing the light so that only that received from one picture element of the subject is effective at any given instant in producing a signal. This signal is then treated in similar fashion to the sound signal, and controls another transmitter working on a different wave-length. It is conceivable, but not probable, that the same aerial may be used for both transmitters.

The synchronizing signal is produced as a result of the scanning operation, and constitutes a third form of communication. To avoid the need for providing a third channel, it is usually superimposed on the vision channel in such a way that it occupies the momentary interval between strips or

pictures, and can be separated out again at the receiver. There seems to be no practicable way of using the sound channel to carry synchronizing signals, for it is required continuously.

It is important to note that quite different types of apparatus, both transmitting and receiving, may be freely interchangeable on what may be called a given television *service*; while apparatus working on the same principle may not be interchangeable. It is the number of scanning lines per picture, the sequence of scanning, the number of pictures per second, the ratio of picture width to depth, and the nature of the synchronizing signals, that distinguish one service from another. It is obvious that service, in this sense, should be unified as much as possible. There is scope for any amount of diversity in the apparatus which is devised to make use of a single service.

The English language can be written by typewriters of many different makes. But all these makes of typewriter fail when one changes to the Japanese language. Language, in this illustration, typifies a television service.

The Receiver.

Leaving the transmitter and going to one of the receivers that it serves, we have the receiving aerial. Generally only one aerial is needed; and the first part of the receiver itself, even, may be common to sound and vision. Farther on, however, the signals are sorted out and amplified separately until the sound signal is strong enough to work a loud speaker; the synchronizing signal is strong enough to control the pace of the scanning apparatus; and the light signal to control a source of light, making it bright or dark according to the portions of the subject being scanned at that moment. In some systems the signal makes the source of light itself vary, while in others a constant beam of light is intercepted and controlled. The portion of the receiving screen illuminated by the light is made to correspond exactly with the portion of the subject by means of the receiving scanner, which must

work in precise sympathy with the transmitting scanner. The methods which are adopted for effecting the scanning may be quite different from those at the transmitter.

Although the chief parts of the dual receiver are shown separately, the tendency is to enclose them all within a single cabinet.

It is rather difficult to show the equipment in general even in such bare outline, because there are systems that differ even as regards the fundamental processes shown. The latter, however, are common to the majority of systems that have been and are being developed; and exceptions will be noted in the appropriate places.

Already the files of the Patent Office are swollen with specifications of devices for carrying out the processes required for television. These are chiefly: the scanning systems (transmitting and receiving); the method of illuminating the subject and dealing with the light on the way to the transmitter; the photo-cell; synchronization; controlling a light source by the output from the receiver; and the methods of presenting the resulting picture to the eye. With them must be included modifications to the radio parts of the equipment to enable them to handle the wide range of frequencies represented by high-definition television signals.

There is room in this book to refer to only a few of the most favoured methods.

CHAPTER III

Mechanically Scanned Systems

The Nipkow Disc.

What almost deserves to be called the classical method of scanning is that which makes use of a perforated rotating

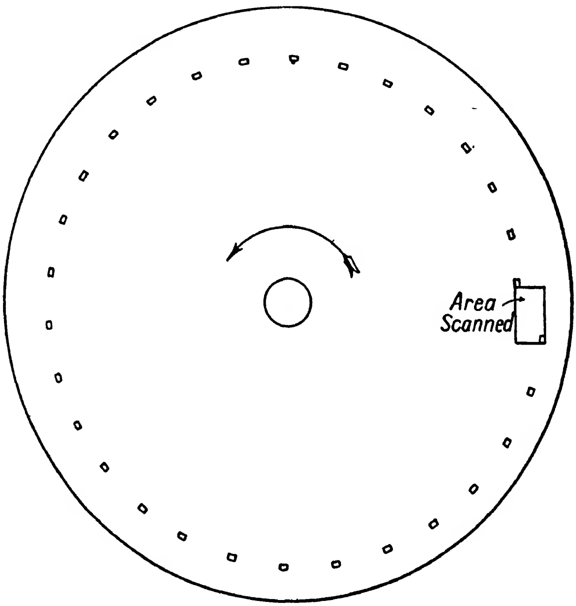


Fig. 3

disc, called, after its inventor, the Nipkow disc. It may be used at transmitting or receiving ends, or at both.

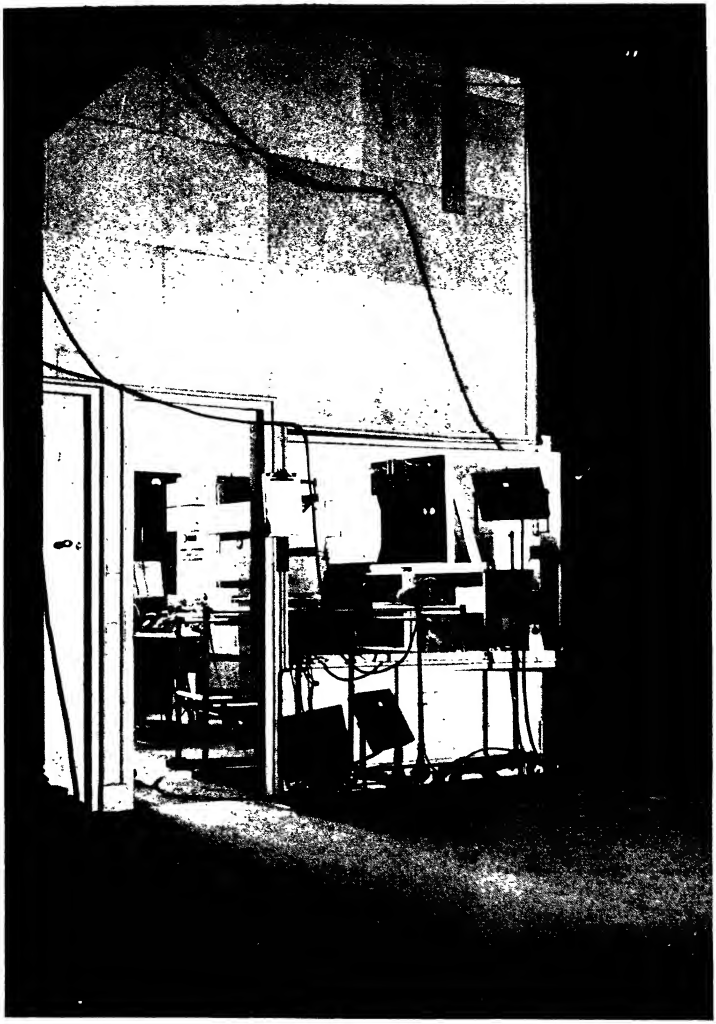
Fig. 3 shows how the holes are arranged in relation to the

frame through which scanning is effected. Imagine oneself looking at a scene through such a frame, with the disc rotating in an anti-clockwise direction close up against it. At the instant illustrated the disc is in such a position that there is a hole at the bottom right-hand corner of the frame, and consequently this is the only part of the scene that is visible. If it happens to be a brightly illuminated part, some of the light passes through the hole into the eye. By substituting a photo-cell for the eye, an electric current is set up by the light in a manner to be described later.

As the disc rotates, the hole travels up the edge of the frame, successively revealing further parts of the scene in its stride. These affect the photo-cell in their turn, giving rise to corresponding electric signals. The parts are so dimensioned that just as one hole passes beyond the area of the frame, another comes on to it from below, displaced to the left by the diameter of one hole so that it scans entirely new ground. The third hole deals with a strip still farther to the left; and so on, until the whole of the subject has been scanned.

Obviously the number of scanning lines is equal to the number of holes in the disc, and the number of pictures per second is equal to the number of revolutions of the disc in that time. In the low-definition system that has been used by the B.B.C. there are 30 holes and $12\frac{1}{2}$ pictures per second; therefore there are 375 scanning lines per second, and the disc is required to make 750 r.p.m. As the height of the picture is $\frac{7}{3}$ of the width, each scanned strip is 70 times its width, giving 70 picture elements per strip, 2100 per picture, and 26,250 per second.

The light reflected from a whole scene or picture through a small frame is, in general, not dazzlingly great. The amount reflected from $\frac{1}{2100}$ of it is therefore very small indeed, and likely to produce such a slight effect on even the most sensitive type of cell as to be inappreciable. In the early attempts the illumination had to be so intense to do anything at all that the glare was intolerable for living subjects.



B B.C. Copyright Photo

B.B.C. Studio for Low-definition Television, with Control Room beyond

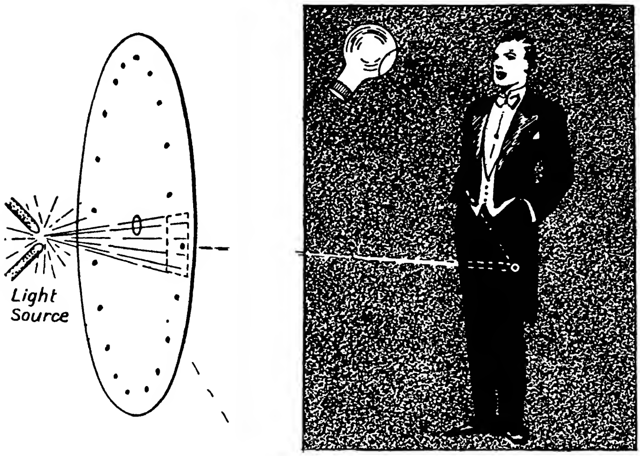


Fig. 4

The light and the photo-cell were therefore interchanged, so that the scanner projects a moving spot of light over the subject, and the photo-cell picks up the reflected light direct. Only the light which is actually needed at any instant reaches the subject, so it may be made much more intense than when the whole is continuously flooded with light.

This arrangement is shown in fig. 4. The scanner illuminates the subject in a sort of flickering twilight. An observer in the studio is hardly conscious of the continual changes in brightness as the spot moves over light and dark parts of the subject in turn, because the impression conveyed by the human eye cannot change in less than about a tenth of a second. This " persistence of vision " is, of course, the imperfection in the sense of sight, of which advantage is taken to create the illusion of moving pictures either in television or cinematography.

The Photo-cell.

But the photo-cell is designed to respond in less than a thousandth, or even a millionth, of a second; and it follows all

the rapid variations, producing electric currents in proportion. The type which is universally used is rather similar to an ordinary wireless valve, in that it has a cathode and an anode enclosed in an evacuated glass bulb. The cathode of a valve is made to emit electrons by heating it. The photo-cell cathode emits electrons when light falls on it.

This is made possible by sensitizing it with a coating of one of the alkaline metals, usually potassium or caesium.

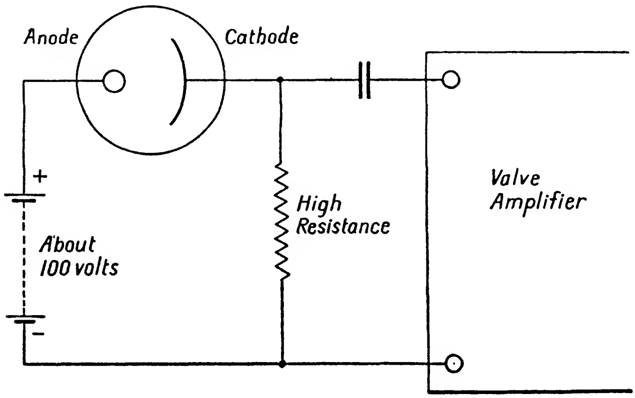


Fig. 5

There is no need for a grid to control a superabundant supply of electrons, as in the valve. The supply of electrons in practical lighting conditions is very small indeed, so all of them are used; and the amount emitted is directly proportional to the intensity of light.

They are attracted across from the cathode by a suitable voltage applied to the anode by a battery, and constitute a small electric current in the circuit thus formed (fig. 5). The current is passed via a high resistance, and the resulting signal voltage is amplified in exactly the same way as in the ordinary resistance-coupled amplifier. A large number of stages of amplification are necessary before it can control a broadcasting transmitter. As the current is so very small,

great precautions are necessary to prevent interfering disturbances from being picked up at this point. The cell itself and the leads from it (which should be as short as possible) are thoroughly screened.

It is possible to enlarge the light-released current very considerably by introducing a small quantity of inert gas into the cell. The collisions between the moving electrons and the molecules of gas knock further electrons out of the latter, and these help to swell the crowd. But, as may be imagined, there is less certainty about the final result; and in addition to this the response is not so rapid. So gas-filled cells have been abandoned for television. A better method of multiplying the electron stream will be described in Chap. V.

A number of cells are sometimes assembled into " banks ", and mounted on portable stands for studio use. A little thought will show that in the light-spot system of scanning, in which the light source and the photo-cells are interchanged, the cells are positioned as if they were stage lights. If they are overhead, for example, the " brightest " signals are transmitted when the light spot is touching the upper parts of the subject, while those which are not in a direct line with the cells are signalled as dark, however bright they may actually be.

Receiving Apparatus.

At the receiving end the video * signals are tuned in and amplified in much the same way as the audio signals, but instead of leading to a loud speaker they are used in some way to control the source of light. The ordinary metal-filament types of electric light are quite incapable of the rapid fluctuations necessary for this work. Neon lamps were the first to be used successfully. They require more power to modulate them than the domestic loud speaker; and the

* The convenient American practice is here adopted of referring to the varying electric currents produced in the sending or receiving apparatus as a result of the televising process as *video* currents, to distinguish them from the *audio* currents corresponding to the audible part of the programme, and the *radio* currents on which both are carried.

light is poor and of an unsuitable red colour. Better lamps have been specially developed such as those including mercury vapour, or various combinations of gas filling.

A Nipkow disc is driven by a small motor at exactly the same speed, and the same instantaneous angular position, as the one at the transmitter. Assuming, as we did before, that the small portion of the subject covered by the scanning spot in the bottom right-hand corner is light, then the video signal is such as to cause the light source at the receiver to shine brightly, and as it is viewed through the receiving disc when the hole which is at that moment within the picture frame is occupying the bottom right-hand corner, the result, so far as that small portion is concerned, is a representation of the original subject. During the next $1/12\frac{1}{2}$ of a second (according to the low-definition system) every portion of the picture is reproduced in this way; and *although only a single spot is actually visible at any one moment*, the eye is unable to realize that the whole area is not reproduced simultaneously.

Various modifications have been used in practice, employing lenses and other optical devices to improve the brightness by making use of more of the available light, or to project the image on a screen.

The Mirror Drum.

It is difficult to get much light through the minute hole in a Nipkow disc; therefore much attention has been devoted towards better scanning systems. The scanner which has been used for the last few years to transmit the B.B.C. programmes by the Baird low-definition system, and also in a large proportion of the receivers, is the mirror drum. This is a wheel carrying on its edge as many parallel strips of mirror as there are scanning lines (fig. 6). Each is set at a slightly different angle, so that, when the wheel turns, a beam of light projected on to its edge is reflected by the mirrors in a series of vertical lines which stand side by side in the same way as when produced by the Nipkow disc. But with the aid of

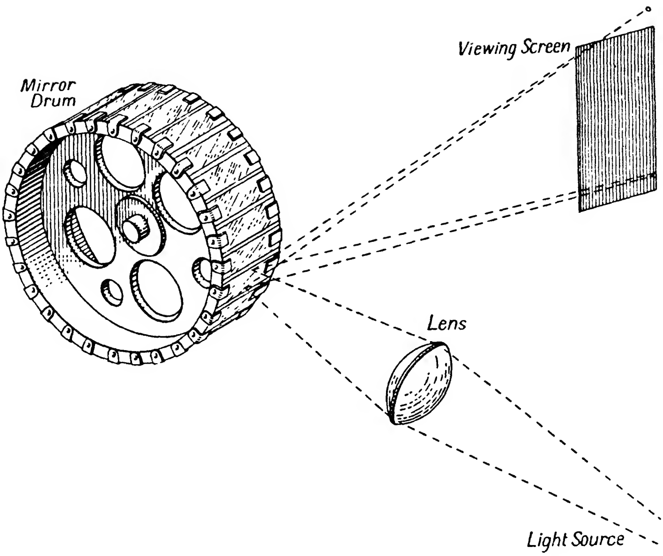


Fig. 6

lenses it is possible to project much more light. The improvement is comparable with that of the modern camera, with its lens, over the pinhole camera.

Limitations of Mechanical Systems.

There are many other varieties of mechanical scanner, which have been used for low-definition work with more or less success. The recommendation by the Television Committee of a minimum of 240 lines for public service makes the outlook for any mechanical system appear extremely bleak.

Take the mirror drum, which is quite satisfactory on a 30-line system. It requires some constructional care, but is not impracticably difficult, to mount 30 mirrors around a drum with sufficient accuracy for scanning. It is quite a different matter to build a wheel carrying 240 mirrors, with their angles correspondingly more accurately adjusted. Allowing

for the fact that to get 25 pictures per second it must be revolved twice as fast, the mere mechanical difficulties are enormous. Such a piece of machinery is almost out of the question in a home receiver.

It has been explained that in the 30-line system only $\frac{1}{2100}$ of the picture is illuminated at any instant. Consequently there is the difficult problem of providing an average of 2100 times the brightness of the whole picture as it appears to the eye. This difficulty is very much greater in a 240-line system, where the ratio goes up from 2100 to 76,800.

The mechanical difficulties are not so serious at the transmitting end, where the restrictions on cost and space are relatively unimportant. It is the problem of illumination that has chiefly set the trend of invention. The moving light-spot provides too little stimulus to operate a photo-cell well above the level of inevitable stray disturbances such as amplifier noises. (The word " noise " is quite illogical in this connexion; it is a legacy from sound transmission.) And of course it is altogether inapplicable to outdoor subjects such as public events.

Intermediate Film.

Most of the concerns actively engaged in television development have made considerable use of the cinema film to dodge these difficulties. Where the subject is not already in the form of film, it is recorded thereon by means of a cinema camera, which can now be made to yield results under almost any conditions. The film immediately passes through developing, washing, and fixing tanks, and is scanned while still wet (fig. 7). Special attention has been devoted to speeding up these processes, whereby the total delay introduced between photographing and scanning has been cut down to less—in some cases considerably less—than 30 seconds. Such a delay is negligible so far as the televiewers are concerned; and they need be none the wiser, unless the broadcast happens to include some such clue as the striking of Big Ben.

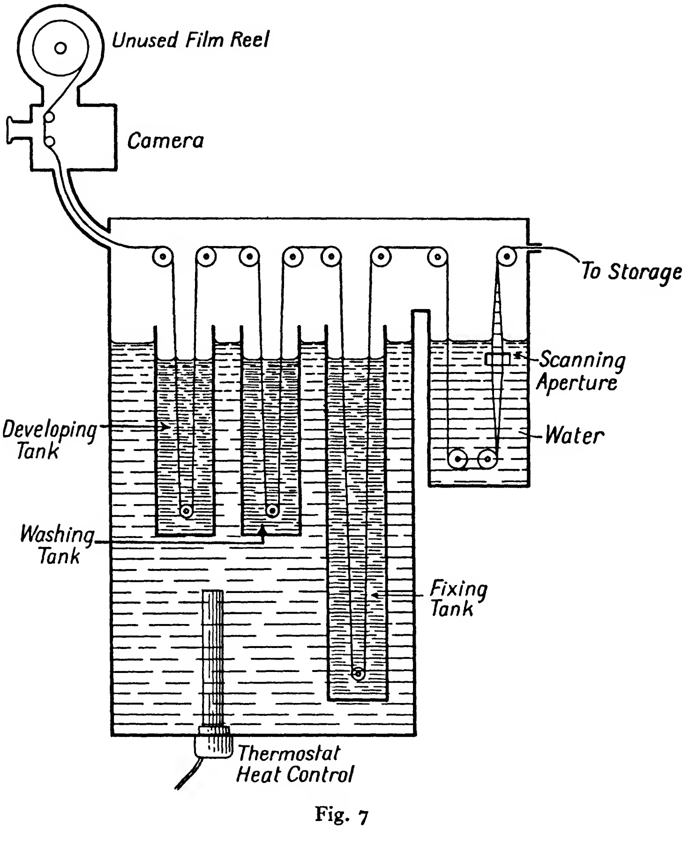


Fig. 7

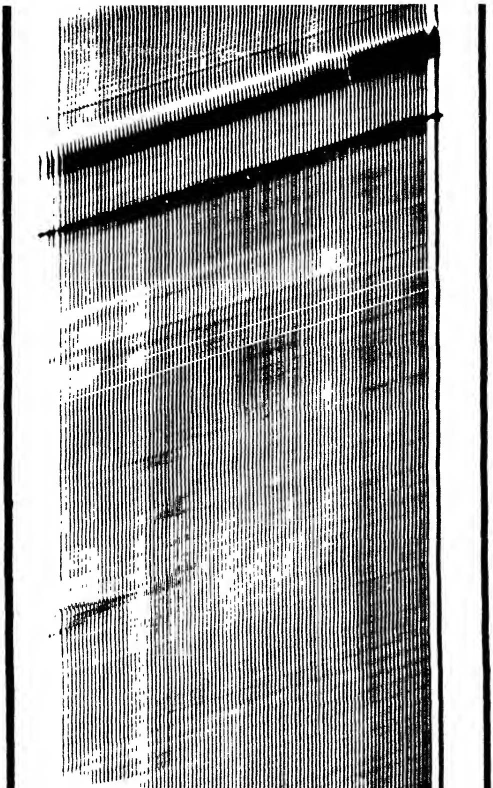
The sound must also be delayed by an equal amount, of course, so as to synchronize with the picture. There are two methods of doing this. One is to record the sound on the same film, exactly as in " talkie " work. The other is to record it magnetically on an endless steel tape or wire, which passes around from recorder to " pick-up " in the delay period, and is " wiped clean " by a permanent magnet before reaching the recorder once more. The disadvantage

is that the sound is lost, so that the film cannot be used as a permanent record. To save the cost of film when a permanent record is not needed, the intermediate film process has been further elaborated by removing the used emulsion and resensitizing the film, so that an endless band of it can be used continuously.

In any case, the standard size of film is unnecessary; the Baird Company have been working with film approximately one-third of the standard width—about the same size as the Baby Pathé.

The conditions of scanning are much more favourable and under control when the scene is reduced to film. The further advantage of a simultaneous record of the programme is obvious. An interesting feature is that the need for providing the slower of the two scanning motions is abolished, as it is obtained automatically by the motion of the film past the scanner. Instead of passing in jerks, as through a cinema camera or projector, the motion is continuous and steady. A modified Nipkow disc is used for scanning in the Baird system. There are many possible methods, however.

This film technique does nothing to ease the situation at the receiving end. It always has to be borne in mind by television inventors that although a fair amount of complication and expense can be tolerated at the transmitting end, every effort must be made to reduce the receiver to the simplest possible equipment. The mechanical devices that have served for 30-line television become unwieldy when modified for 240-line work. Indeed, it is taken for granted by many people that only electrical systems such as the cathode ray tube to be described in the next chapter need be considered in future. Those who have studied the Scophony system, however, are likely to entertain some doubt as to whether the cathode ray tube will go entirely unchallenged.



Courtesy of Scophony Ltd.

Specimen of Scophony "Stixograph" Film

The Scophony System.

The inventor of this system, G. W. Walton, prefers it to be described as an optical rather than a mechanical system; for, while one small moving part is necessary for the actual transmission or reception of pictures, the fundamental principles are entirely optical. It is impossible in a small space to do justice to the full theory that has been worked out by the inventor, and which embraces a far wider scope than its application to television; but he himself has contributed a valuable series of articles on it to *Television*, March-July, 1934, to which reference should be made.

The basic idea is that a picture, which occupies two dimensions, can by a suitable optical device be perfectly represented to any desired fineness of definition in a one-dimensional form, called a stixograph. A *moving* picture, which requires the additional dimension of time, can therefore be perfectly represented in a two-dimensional medium, such as film. The standard cinema system is a makeshift; it merely provides a succession of discontinuous still pictures that give an illusion of a moving picture. Admittedly it is a very good makeshift, or it would not have achieved such success. But one wonders what would have happened if the stixograph had got in first.

To anyone familiar with cinema practice, it must seem incredible that a picture can be taken or shown with continuously exposed film, passing steadily through the machine at a fraction of the rate at which standard film is jerked along.

Going right back to our analogy of transmitting a printed page by dictating it word by word in an agreed order, line by line; the stixograph corresponds to a page of wording redistributed into the form of one long line. There is no limit to the number of ways in which such a redistribution could be carried out; it could be done, for example, in the form of unintelligible code. Pictures can easily be transmitted with secrecy in the same way.

Adopting the same form of distribution as that used for

scanning in standard systems, the stixograph is formed by means of an "echelon"—a stepped series of prisms, or reflectors. One form that is used in television is the mirror screw. If one imagines a stack of safety razor blades made of brass, with very narrow mirrors where the edges should be, strung together on a spindle passed through the centre holes, and skewed around into a spiral staircase formation, one has a good picture of a mirror screw. The mirrors are formed by polishing the edges of brass plates and rhodium plating them. The angle between any two adjacent mirrors is such that the strips of picture, reflected by each, join up end to end to form the stixograph. In conjunction with an optical system of lenses, &c., a virtual image is produced and can be scanned by the process of rotating the mirror screw.

At the receiving end it is possible to view the picture by looking at the reflection of the modulated light source in the mirror screw. The light source in this system must take the form of a narrow slit, parallel to the axis of the screw. Readers who have followed the action of previous receivers will have no difficulty in seeing how the image is built up by these means.

The Kerr Cell.

We have already observed that there are difficulties in making the radio receiver modulate the light source direct. An alternative method, which has been applied to all the systems of scanning yet described, is to modulate the light after it has been emitted from the source. One can imagine this being done in an elementary sort of way by controlling the light mechanically with a moving shutter. This is actually done in talking film technique. Television employs a rather more complicated optical method which must now be briefly described.

The waves of which ordinary light consists oscillate at all angles in a plane perpendicular to their direction of travel.

One can illustrate this by taking hold of the end of a horizontal rope and sending waves along it by waving the hand up and down, side to side, and, in fact, any way, indiscriminately. Certain crystals, cut into prisms called Nicol prisms, have the power of passing on only those waves that oscillate at a particular angle—say, up and down. The light appears quite normal to the eye; but is actually " plane polarized " light, and can be distinguished by passing it through another Nicol prism. If the second is held at the same angle, the light passes through; but if it is turned round to a position at right angles to the first it is evident that no

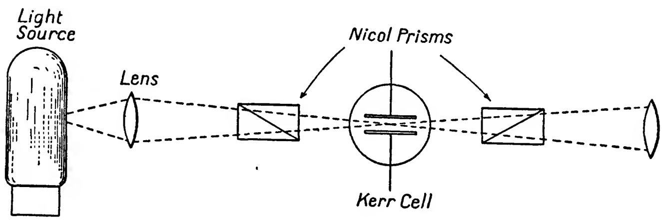


Fig. 8

light can get through both prisms. The intensity of the light can be controlled from zero to full by rotating one of the prisms through a right angle.

That form of control does not offer any very useful possibilities; but a Scottish professor named Kerr provided a practical key to the situation by a discovery that finds its practical outcome in the Kerr cell. In its modern form, due to Karolus, it consists of a group of interleaved plates, strongly reminiscent of an electrical condenser, immersed in nitrobenzene. When two prisms are set so that the second of them extinguishes the ray of light passing through the first, and the Kerr cell is placed between the prisms with the ray passing through the liquid between the plates (fig. 8), an electric stress produced by a difference of voltage applied to the plates causes the plane polarized light to become more

like ordinary promiscuous light. The second prism is therefore able to pass some of it, the proportion depending on the voltage. The action is often erroneously described as a rotation of the plane of polarization; that is quite another effect, discovered by Faraday.

The signal voltages available from the radio receiver are thus able to modulate a light source, which can then be distributed by any of the types of scanner described.

The efficiency of the Kerr cell and prism system has recently been greatly improved; and the Scophony concern claims also to have produced a new form of light modulator, that overcomes a serious difficulty of the Kerr cell; namely, that owing to its fairly large electrical capacity it becomes a prohibitively heavy load at the high frequencies involved in high-definition work.

An important advantage of the mirror screw in the receiver is that in conjunction with simple optical arrangements it projects quite a large picture on a screen, after the manner of " home movies ".

At very high definition, say over 250 lines, it becomes advantageous to employ a stationary echelon device, with a comparatively simple rotating scanner.

Synchronization.

All the receiving systems described in this chapter have this in common, that they have to be motor driven, at such a speed as to keep exactly in step with the transmitter. The latter, if also motor driven, is usually run by a synchronous type of motor from the A.C. mains. If the receiver can be connected to the same supply system, it might appear that by also using a synchronous motor, absolute synchronism would be ensured; in the same way that electric clocks can be run on any time-controlled mains. Now that most of the electric supplies are linked to the " Grid " that stretches all over Great Britain, this seems to be a ready-made synchronizing medium for television.

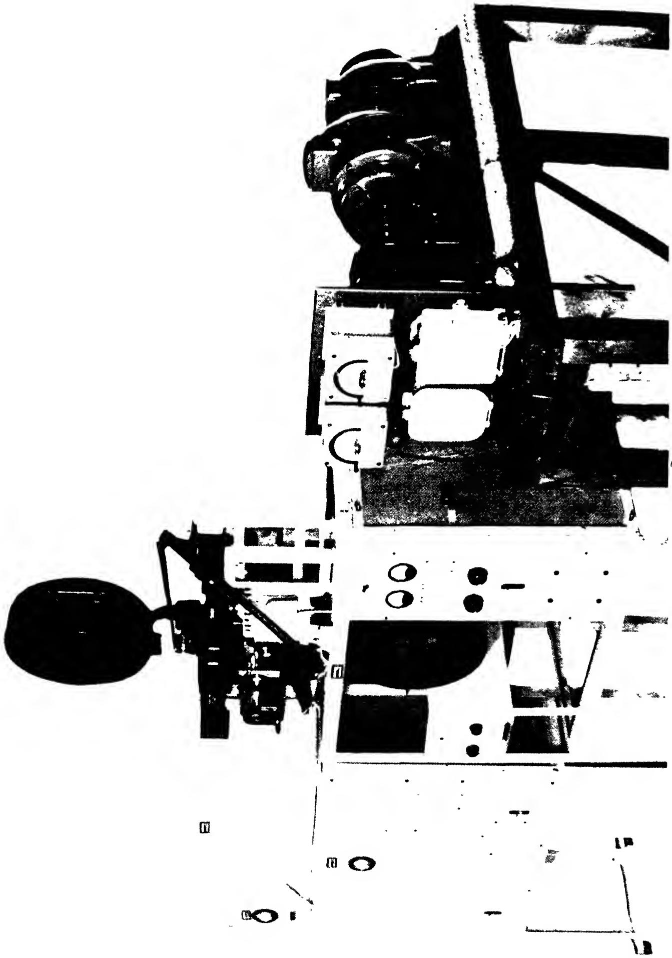


Photo courtesy of Scophony Ltd.

Scophony 120-line Transmitter

It is true that this method has been used, but it is not so perfect as might appear. It is not enough for the motors at both ends to make exactly the same number of revolutions in a given period. They must maintain exactly the same angular relationship, or *phase*, at all times. Unfortunately the phase is liable to vary slightly over a supply system, according to the distribution and nature of the load; so that one motor may be a fraction of a revolution fast or slow.

In a 30-line system, a thirtieth of a revolution—12 degrees—out of phase corresponds to the height of the picture; so, if the picture is to keep steady within a twelfth of its height, the motors must be within 1 degree for only a very poor standard of steadiness. The higher the number of lines, the greater the problem.

Some sort of synchronizing signal is therefore sent out as part of the service. The practice in the B.B.C. 30-line service has been to leave a proportion of the height of the picture blank, so that each scanning line ends with a " black " signal of definite duration. Black corresponds to maximum output from the receiver; and these periodical strong signals are used to energize electro-magnetic coils close to a toothed wheel on the motor spindle. This is, in fact, a sort of auxiliary synchronous motor. It would be uneconomical to attempt to provide signals strong enough to drive the whole machine, so the brunt of the work is borne by a non-synchronous motor set to run as nearly as possible at correct speed. A tooth of the wheel should be in line with the synchronizing coils each time the signal occurs; if there is any tendency to depart from exact synchronism, the magnetic tug of the coils on the teeth accelerates or retards them according to whether they are approaching or receding. The effect is that of being geared to the transmitter by a drive that is liable to slip unless it is reasonably closely in step to start with.

It may happen that the receiving scanner is pulled into step in such a way that the division between the pictures occurs somewhere in the field of view instead of at the top;

so that the picture is broken up, the bottom portion appearing at the top. It is incorrectly " framed ", owing to its being a portion of a scanning line ahead of or behind the transmitter. The Baird 30-line receiver permits the synchronizing coil mounting to be rotated through a small angle to adjust this. Another possible fault is for the picture to be divided vertically, which means that it is several complete scanning lines displaced relative to the transmitter. The remedy is to retard the driving motor slightly to let a sufficient number of lines slip past, and then to relock it in the correct relationship. In a horizontally scanned system, of course, vertical and horizontal are to be interchanged in this paragraph.

Owing to the small angular tolerance, synchronizing is a considerable problem in mechanical scanning systems. Another difficulty is that a black object parallel to the synchronizing border is liable to usurp the function of the synchronizing signal, pulling the picture to pieces. Other limitations and difficulties in mechanical scanning systems have been noted during the course of this chapter; and as early as 1908 it was suggested that the future of television lay with the cathode ray tube, in which movement is confined to that of the amazingly nimble electrons that follow our bidding in wireless valves more lightly than any Ariel.

CHAPTER IV

Cathode Ray Systems

The Cathode Ray Tube.

The importance of the cathode ray tube in the television tool-box can almost be compared with that of the valve in ordinary broadcasting. What is of greater interest at the moment is that the principle of working can also be usefully compared. A valve, whatever its type, consists basically of a cathode (meaning negative electric pole) which when heated provides a supply of electrons. These electricity carriers can be attracted across to the positive pole, the anode, when it is maintained at a sufficient number of volts positive in relation to the cathode. The various grids that are interposed, the number depending on whether the valve is a triode, tetrode, pentode, hexode, heptode, or octode (that is about as far as the valve-makers have gone at the time of writing), are designed to control the electron stream in useful ways. This stream constitutes an electric current, and one is chiefly interested in what can be done with the current after it has left the valve, by way of the connexions provided.

The cathode ray tube includes the same elements, but the electron stream is little esteemed as an electric current; it is valued for what can be done with it inside the tube by causing it to impinge on a sensitive chemical surface.

A fairly clear picture of the action of a cathode ray tube is to imagine somebody playing a fire hose against the inside of a glass dome roof. A person situated above the building would see a splash on the glass at the spot where the stream of water was striking it. If the wielder of the hose were

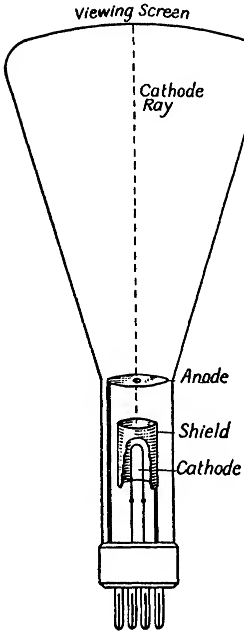


Fig. 9

sufficiently dexterous he could produce a crude sort of pattern on the dome by waggling the nozzle about a bit.

The cathode (see fig. 9) is usually run at less than one volt through a suitable resistance from a 2-volt accumulator. There are certain difficulties in working it on A.C., but no doubt these will shortly be overcome. The anode is given a considerably greater potential than the average valve—from 500 to 2000 or more volts—so the electrons that are liberated from the cathode are accelerated very rapidly indeed towards the anode, and ordinarily they would get no farther in the free space inside the tube. A third electrode, corresponding to the grid of a valve, is the *shield*, which is given a negative potential of the order of one-tenth that of the anode positive potential. The electrons, being themselves negative, are repelled by this negative potential, and huddle close together in a narrow stream along the axis of the cylindrical shield. In doing so they find themselves shooting through a hole in the anode provided for that purpose; and travelling at a good many miles per second, so that they hit the widened end of the glass tube before the attraction of the anode has been able to stop them.

Focusing.

The end of the tube is coated with one of the several chemical materials that have been found to glow as a result

Cathode Ray
Tube

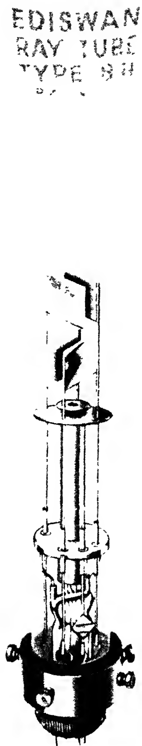


Photo-cell as used for Television,
made by the Oxford Instrument Co.

Facing p. 34

of the impact of electrons. As they have been concentrated into a narrow beam, a small bright spot of light is produced on this screen. In practice it is necessary to take further steps than those described in order to ensure that the beam of electrons, or " cathode ray ", is sufficiently concentrated. One method, which is very useful for some purposes, is to introduce a small but definite trace of an inert gas into the tube. This serves the purpose in a way which need not be considered here in detail, because it carries with it certain disadvantages for television, and the present tendency is to pump the tubes to a very high vacuum and effect the " focusing " of the beam by other means.

One of these is to provide two or even more anodes, having suitably graded voltages. The Ediswan BH-tube has two; the second is maintained at about 2000 volts, and the first is varied around 700 until focusing is satisfactory. As the spot of light on the screen is to reproduce the picture element, it must be adjusted to the right size.

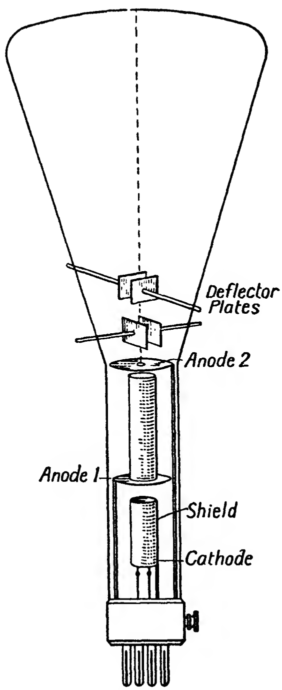


Fig. 10

Modulation.

The next requirement is to be able to modulate the light by the output from the vision receiver. This is much more easily done than by the methods described in the last chapter; a variation of the order of 20 volts applied to the shield electrode completely modulates the spot of light. The current taken is extremely small, so actually the

picture reproducer demands far less power than the loud speaker; the smallest sort of power valve is adequate.

Deflection.

That does not end the variety of ways in which the cathode ray is manipulated. The scanning—or rather redistribution—also can be carried out by applying electric signal potentials to the tube. Two pairs of parallel plates are fixed just beyond the anode or anodes, in such a way that the beam passes between both of them (fig. 10). When a difference of potential exists between one pair of plates the beam is deflected from its course to an extent which is proportional to the number of volts potential difference. The second pair of plates is set at right angles to the first, so that the deflection also takes

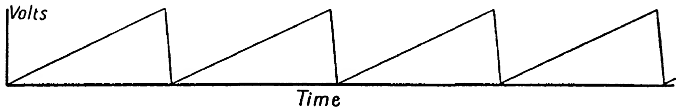


Fig. 11

place at right angles; and, by making use of both pairs, the spot can be deflected to any part of the screen.

To copy the motions of a high-definition transmitting scanner, one pair of plates must move the spot steadily across the screen (assuming horizontal scanning) and then return it almost instantaneously for the next line, repeating this 6000 times per second. The other pair must meanwhile move the spot up and down the screen 25 times a second, to space out each 240 lines into a complete picture frame. The voltages to be applied to the deflecting plates must obviously be of the saw-tooth form shown in fig. 11. It is no use, then, applying an ordinary oscillating voltage, having a smooth wave-form. Special "sweep" or "time-base" circuits have been evolved; and, as it is desirable to be able to control (1) the frequency, (2) the length, and (3) the position of each of the components of spot movement, this part of the equipment is apt to be rather complicated.

There is not space here to include detailed descriptions of the various circuits, but the basis of many of them is the relatively slow charging of a condenser at a uniform rate controlled by a tetrode valve, and its sudden discharge through a gas-filled discharge tube, such as a neon lamp, "Thyratron" or mercury vapour or helium relay.

With the object of providing a simpler and cheaper set, use is alternatively made of an effect which can sometimes undesirably be got in a radio receiver with reaction control, by turning it far past the oscillation point. The oscillations, though themselves at an inaudible frequency, increase to such an extent that they momentarily paralyse the valve that generates them. The paralysing over-charge on the grid condenser gradually leaks away until it gets to the point where oscillation is possible once more, when it repeats the cycle of events indefinitely at a frequency which is audible. It is usually termed a "squegger". The sudden charge of the condenser, followed by a slower discharge, yields a saw-tooth wave-form.

Synchronization.

The frequencies of each of the deflecting signals must be kept absolutely in step with the transmitting scanner.

As in the mechanically driven viewers, only approximate synchronism is possible by means of the local apparatus, which must therefore be constantly under check by the synchronizing signal sent out with the vision signals.

The principle employed is to adjust the local deflectors to be a trifle "slow". At the time when the spot is due to be returned, therefore, the deflector circuits are in such a condition that a very small extra impulse applied to the "tripping" device is enough to operate it. The synchronizing signal is separated from the rest of the matter received from the television broadcaster, and fed into the deflector circuits so as to act as the last straw. To change the simile, it is like a trigger of a gun intended to be fired at an exact moment.

Some local force is applied to pull the trigger nearly to the critical point in readiness, and a time signal received from a distance is strong enough to touch it off.

There are various possible types of synchronizing signals and methods of separating and applying them. The Baird low-definition scheme, with its "maximum black", has already been explained. There is no distinctive picture frequency signal; for the number of lines is, in the mechanical reproducers commonly used, unalterably fixed by the construction. And the line signal is not perfectly distinguish-

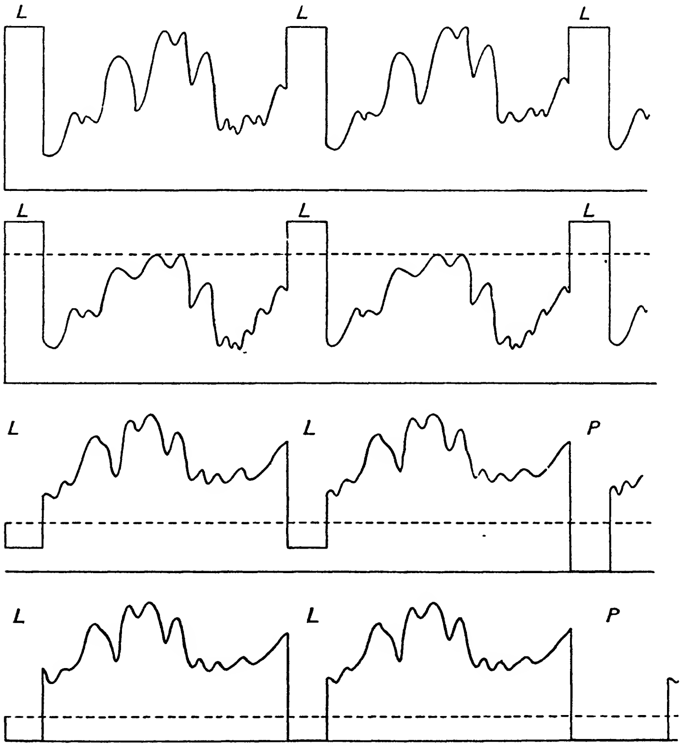


Fig. 12

able from that due to a black object in the field of view.

An alternative is to make the synchronizing signal stronger than the greatest possible vision signal, so that it can be definitely separated by such simple means as an overbiased valve. Another system fixes the zero vision signal at, say, 20 per cent of the unmodulated transmitter output. There is a margin of that amount for superimposing a synchronizing signal that is *less* than the vision signals.

We have seen that, by simply adjusting the deflector circuits, the number of lines forming the picture on a cathode ray tube screen can be varied. The line synchronizing signal ensures that the line shall be of the correct duration, but so far there is nothing but accuracy of adjustment to ensure that the number of lines per picture shall be exactly 240, and not 239 or 241.

In high-definition systems, then, a distinctive picture-frequency signal is practically essential; and it can be differentiated from the line-frequency signal by either intensity or duration. For example, if the vision zero were fixed at 20 per cent modulation, the line-frequency signal might reduce it to 10 per cent and the picture-frequency to zero. Alternatively the latter might last longer. A comparison of these signal systems is shown in fig. 12, in which L indicates a line synchronizing signal, and P a picture synchronizing signal. Obviously the receiver must be designed to separate and apply them, and it might be a difficult matter to change from one system to another.

Practical Considerations.

The tube control apparatus has subsidiary controls for adjusting the lengths of the spot deflections—which decide the size and proportions of the picture—and for centring the picture on the screen.

Cathode ray tubes have been produced with screens over a foot in diameter for obtaining a correspondingly large picture. Such tubes are necessarily very bulky, as the

deflection angle must be kept reasonably low to prevent image distortion. One can enlarge the image in various ways; but at the present time there appears to be more possibility for large screen projection in a mechanical system. The cathode ray system is much more complex in its parts, but there are obvious advantages in carrying out the rapid movements of high-definition scanning by electrical rather than mechanical means. The two general systems are often compared as regards the light that is available for composing the picture, but at the present date the development of both is not sufficiently final to allow of unqualified pronouncement.

The cathode ray tubes that were adapted to television from other uses gave a green or blue light which was not very pleasing. The problem of providing black-and-white or sepia pictures seems now to have been solved.

The tubes are sensitive to external electric or magnetic influences; even the earth's magnetism moves the spot appreciably, but as it is a steady deflection it can easily be neutralized by the deflector. Varying effects, produced by A.C. transformers used in the apparatus or elsewhere, destroy the clearness of the picture. Screening the tube in a thick iron cylinder is helpful, but adds to cost and weight.

The whole of this chapter has been devoted to the cathode ray tube at the receiving end, and in the form described this is its most notable application. The same tube can also be used to provide an oscillating light source in one dimension for scanning films, but this is such a relatively simple process as to require no further comment.

Special methods based on the cathode ray tube have been evolved for use at the transmitter, and in particular for scanning scenes direct, which was found to be almost impracticable at high-definition by mechanical methods. We are now to consider these.

CHAPTER V

Special Systems

The Iconoscope.

Photography is now in a very advanced state of development. Adequately exposed pictures of many subjects can be obtained with exposures of a thousandth of a second or even less. But it is asking rather much to require good results with an exposure of one two-millionth of a second, which is all a picture element gets in high-definition television. It is true that feeble stimuli can be amplified almost without limit by means of valves. But valves and their circuits are subject to minute unavoidable internal disturbances which are also amplified; and, unless the desired stimulus is originally at a much higher level than these, it cannot very usefully be employed.

The chief difficulty in high-definition scanning is to collect enough energy from each of the many picture elements in the brief moment allowed for the purpose. The number of electrons released by a photo-cell per element, assuming a practicable intensity of subject lighting, is so small as to be lost among the random circulation of electrons that exists in electrical conductors generally.

This difficulty is ingeniously attacked in the invention of one Zworykin, called the Iconoscope for reasons which Greek scholars will have no difficulty in appreciating. Although the period during which any one picture element is actually being scanned is so small, there is no reason why the light-sensitive cell should not be "exposed" for anything

up to a twenty-fifth of a second; unless it be that at least 76,800 photo-cells are required. This difficulty may appear formidable on first consideration; but Zworykin makes it almost simple. He coats a screen with light-sensitive material in the form of millions of separate tiny specks. Each is in effect a photo-cell.

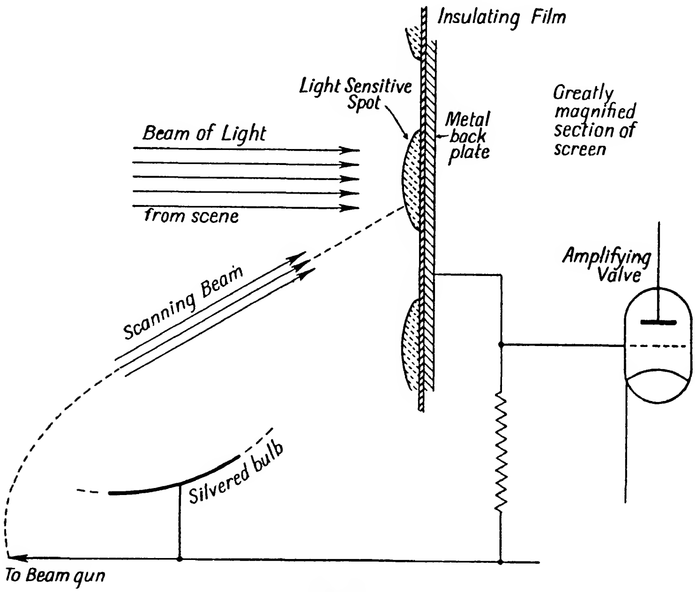


Fig. 13

An image of the subject is focused by a camera on this screen. Each grain of material starts to emit electrons to an extent proportional to the intensity of light falling on that particular spot. The screen is formed of a plate of metal coated with a thin film of insulation. Each spot is therefore electrically insulated; and with the metal backing forms a tiny condenser. When electrons are given off, the spot is deficient in negative electricity, so the condenser is charged positively. What we have at this stage is a vast number of

minute condensers, bearing electric charges proportional to the light at different parts of the picture.

Next consider that the screen is within a cathode ray tube, and that the ray is scanning the screen in the usual fashion. As it flashes across each spot, its negative electrons neutralize the positive charges. In other words, an electric current

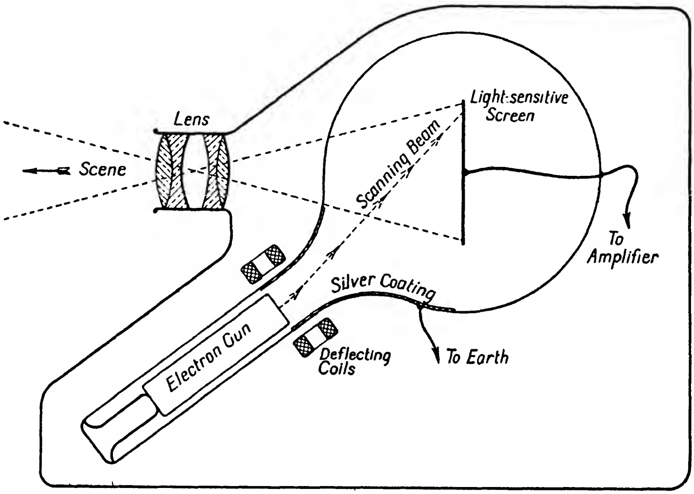


Fig. 14

flows in each case proportional to the charge, and therefore to the local light (fig. 13).

The scanning beam will not cross any particular spot again for nearly a twenty-fifth of a second, giving the tiny photo-cell all the intervening time to accumulate another charge proportional to the average light on that spot during the period. It is easy to understand what an enormous advantage this confers.

Fig. 14 shows how this principle is carried out. The return circuit is via a silver coating to the neck of the tube. For convenience the deflections of the beam are effected by coils

located around the neck, rather than by the usual electric plates.

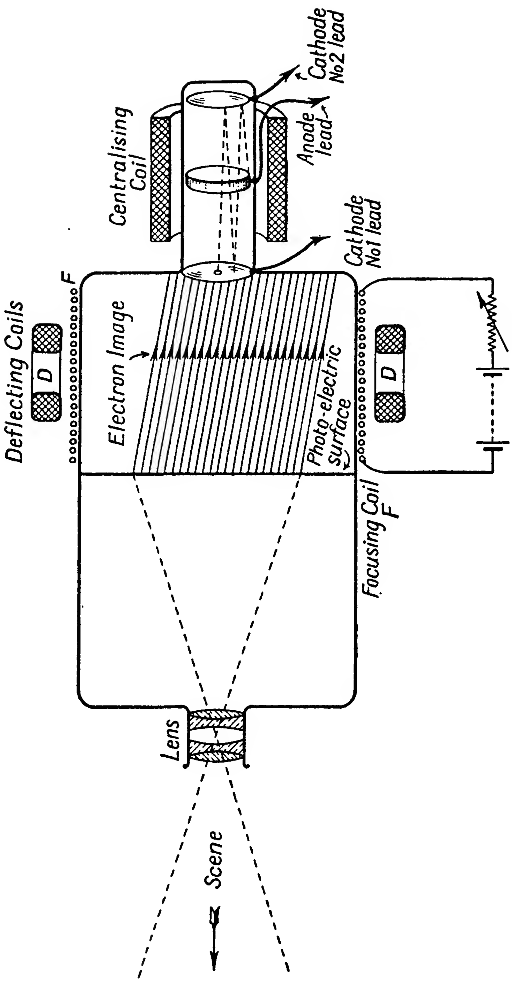
The Image Dissector.

The iconoscope is an important feature of the Marconi-E.M.I. system, which was one of the two to be officially recommended by the Television Committee. The other was the Baird high-definition system which includes an " electron camera ", making use of another American invention—the Farnsworth image-dissector and electron-multiplier. Like the iconoscope it provides for focusing an image of the subject on a light-sensitive surface. The emission of electrons therefore varies from point to point according to the light distribution of the image. Instead of, so to speak, reaping the crop of electrons from each spot in turn, the whole lot are electrically focused and drawn forward a few inches to an opposite screen on which they fall in the same picture formation (fig. 15).

It might be thought that the electrons would break formation en route, seeing that they are not all emitted in exactly parallel lines. And that, in fact, is precisely what they do. But by magnetizing the space along which they pass, by means of a coil wound around the tube, the divergent electrons are made to execute graceful corkscrew movements as they go along. At certain intervals on the way—depending on the strength of magnetization—all the electrons are back again in the same lines as if they had started off right, and by choosing the first of these favourable locations for the screen they strike it in accurate picture formation.

If a cathode ray type of screen were placed here this broad beam of electrons would reproduce a visible image of the subject on it.

In the centre of this plate is a small aperture, so that the electrons corresponding to one picture element pass through and constitute the signal. Instead of the signal collector scanning the cross section of the beam, the collector is fixed and the whole beam is moved by deflecting coils around the tube.



Cathode No2 lead
Anode lead
Centralising Coil
Cathode No1 lead
Deflecting Coils
D
D
F
Electron Image
Photo-electric surface
Focusing Coil F
Lens
Scene

Fig. 15

The signals created in this way being excessively feeble, a new type of amplifier is used, which, incidentally, appears to be capable of quite other applications. The electrons passing through the screen find themselves at one end of another tube called the electron multiplier. A cathode occupies each end, and a ring-shaped anode the centre. A magnetic coil round the outside prevents the electrons from being immediately bagged by the anode, and they reach the opposite cathode, which has a specially prepared surface.

When it is struck by electrons, each one dislodges several more and the whole lot are driven back to the first cathode, where a further multiplication takes place. A number of such oscillations can happen in a ten-millionth of a second and the amplification is enormous. The to-and-fro motion is effected by an oscillatory circuit connected from cathode to cathode. Finally the path of the electrons reaches outwards to the anode whence the signal is tapped.

The results obtained with this system are particularly impressive, and it is undoubtedly going to play an important part in transmission technique.

Velocity Modulation.

A cathode ray system very different from any yet described has been developed in this country by Messrs A. C. Cossor, Ltd. A detailed account of the methods and results up to a year or two ago are given in a paper by L. H. Bedford and O. S. Puckle in the *Journal* of the Institution of Electrical Engineers, July, 1934.

The fundamental principle is that the variations in the intensity of light on the cathode ray screen are obtained, not by varying the *intensity* of the scanning ray itself, but by varying its *velocity*. Hence it is known as the velocity modulation system.

If the direction of the ray is allowed to remain stationary on one spot of the screen, or to move slowly across it, the light is at its brightest. But if it is flashed across at a very

great velocity (such as during the fly-back between lines or pictures in the ordinary systems) the number of electrons hitting any particular spot in the path of the ray is so small that the light is feeble. If, then, the ray is caused to trace the usual scanning pattern over the screen, and is made to speed up over the dark parts of the transmitted image, and slow down over the bright spots, a picture is reproduced without any necessity for modulating the intensity of the ray.

As a matter of fact, one of the main objects of the scheme originally was to avoid having to modulate the ray, which was then a difficult matter to do satisfactorily. Although that particular difficulty has been largely overcome, velocity modulation can still claim important advantages. Chief of these is that, although the apparatus at the transmitter is very intricate, the receiver is greatly simplified. It will be remembered that one of the most troublesome problems in other systems is that of synchronization. Fairly elaborate electrical circuits are needed to control the movements of the cathode ray in step with those at the transmitter. The problem of synchronization is totally absent from the velocity modulation system in its basic form.

It will be evident that to obtain extremely abrupt changes of scanning velocity the transmitter must depend on a cathode ray tube of some sort rather than on a mechanical instrument. Assuming that the subject has been recorded on film and is being scanned by the oscillating spot shining through the film on to a photo-cell, the output from the latter constitutes a video signal—intense at the light parts, and weak at the dark. When amplified these signals can be applied to the deflecting plates of the tube, causing the speed of the spot to be determined by the local density of the film. In this way an image of the picture is produced on the screen of the tube.

If the respective deflecting plates are connected to those of any other tube, the same image must be reproduced by it also. The matter of synchronization does not arise, for the same movements that decide the light graduations of

the picture also comprise their redistribution over the screen.

There is this objection, however, that as there are two pairs of plates, two transmission lines or channels are required to link them. One pair of plates, and corresponding set of signals, is responsible for all the velocity changing as well as the returning of the spot to start another line. All that the other pair does is to bring each line to the side of its predecessor so as to open the strip out into a picture, and after a specified number of lines (meaning the completion of one picture) to return it to the starting line.

The first pair provides the really vital information; the function of the second is subordinate, and can be performed locally at the receiver by a device that displaces the line on receipt of the fly-back signal sent from the first pair. The picture renewal is also controlled by the one signal channel, by arranging a brief suspension of line scanning between one picture and the next.

It has been found advantageous to reintroduce a limited amount of intensity modulation at the receiver, in order to improve the character of the reproduction. This minimizes the difficulty of making either method of modulation alone function satisfactorily over the wide range of illumination needed to reproduce a picture pleasingly. The intensification, as it is called, is optional; but it is evident that a velocity-modulated type of receiver can be worked only from a transmitter of the same type.

There are many minor problems, such, for example, as ensuring a constant number of pictures per second independently of the average illumination of the picture. Otherwise a picture that contained a large proportion of shadow would be scanned much more quickly than one which was predominantly bright.

Bearing in mind that one is usually in difficulty in obtaining sufficient illumination on the screen of the viewer, it will be appreciated that the velocity modulation system is at an advantage in being able to use the light not required on the

dark parts to give correspondingly better illumination elsewhere.

The limitation experienced by the inventors at the time of communicating the results of their work appears to have been that which the methods of Zworykin and Farnsworth are designed to overcome—the signal energy that can be collected during the passage of high-speed scanning. Also when all the other well-developed systems have been along the lines of intensity modulation, non-interchangeability seems to be a distinct handicap.

Colour Television.

In view of the fact that even at the present moment it cannot be pretended that the technique of monochromatic television is really established, it is rather surprising that colour television was demonstrated as long ago as 1928. The technical details have actually been fairly fully worked out, notably by the Baird Company; but, as there seems to be no prospect that colour television of high definition will be a practical proposition for general public use in the next few years at least, only the barest outline follows here.

What has been done has followed the principle of the three-colour process in printing and photography. The subject is scanned three times, once for each colour—red, blue, and yellow. Thinking in terms of the simple Nipkow disc for definiteness, three successive spirals are accommodated, the three sets of holes being covered with red, blue, and yellow filters respectively. When the red spiral is scanning, only those portions rich in red colouring reflect appreciable light. Similarly for the other spirals.

At the receiving end, when the red spiral is in use, arrangements must be made to reproduce the picture in red light. The next display is made with blue light, and lastly with yellow. If the whole is carried out sufficiently rapidly, the colours blend to form a single coloured picture.

Although this may sound rather a difficult thing to carry

out, the difficulties are statistical rather than instrumental. Colour multiplies the number of signals that must be transmitted; it also reduces the available light. Looked at in another way, at a given stage of technical development it is always possible to obtain monochrome pictures of a higher definition than coloured pictures. Until the reproduction of monochrome pictures reaches such a pitch of perfection that the definition can be considerably reduced without noticeable deterioration, it is unlikely that colour television will be much more than a novelty.

Stereoscopic Television.

The same may be said of another rather premature refinement—stereoscopic television—which has been demonstrated under experimental conditions. The difficulty in this case is that two complete television installations are needed. It is at least arguable, however, that the increase in realistic effect is in proportion to the increase in transmitted signals.

Noctovision.

Still another novel form of television was demonstrated some years ago by Baird and called by him Noctovision. The subject is scanned in total darkness by ultra-violet or infra-red light—that is to say light that is too short or too long in wave-length to excite any response in the human eye. Photo-cells can be made that are sensitive, however. In all other respects the processes are identical with those of ordinary television. Although the achievement is one which can be rendered in highly picturesque terms by the lay journalist, it involves very little departure from normal technique. It is not considered likely that noctovision will find any very general application for ulterior purposes, but a possible utility will be mentioned in Chap. VII.

CHAPTER VI

The Radio Receiver

Requirements for Television.

Of great practical interest to the prospective " televiewer " is the question of what sort of receiver is needed. This question is chiefly bound up with what we have called (after the American) the video frequency band; that is to say, the range of frequencies over which the radiation from the transmitter is modulated, and which must be received substantially unimpaired in order to get good visual reproduction.

The corresponding band of frequencies for the audible part of the programme is ideally about 20–15,000 cycles per second, but the transmitter usually stops at about 9000, and the receiver at perhaps 4000, with loss of tone quality.

Even low-definition television calls for a video band of at least 12–13,000 c./s., and, as the maximum results are indistinct enough, any substantial shortening gives a hopeless picture. The precautions to be taken are those that are most favourable to excellent aural reproduction, but must be pressed further.

It is not merely a matter of ensuring a level response to a certain band of frequencies. Very careful attention must be devoted to eliminating *phase* distortion, which is usually neglected in aural receivers.

When all the circuit components are pure resistances, the current and voltage are always in step, or in phase. But when there is inductance or capacitance, intentional or otherwise, the current lags behind or else leads the voltage. Take

an ordinary resistance-coupled amplifier. There is inevitably a certain amount of stray capacitance due to proximities of leads, valve electrodes, and so forth, equivalent to a small condenser connected in parallel with the resistance. When the frequency of the signal to be amplified is great enough for this condenser path to become comparable with that afforded by the resistance, the impedance of the coupling is reduced, and amplification is lost.

That loss is usually the only thing that is taken into consideration. But even when the loss is still quite small—say 5 per cent—the current is displaced by a considerable angle ahead of the voltage. When one is facing a door it makes quite an appreciable angle with its frame before the apparent width is much reduced due to foreshortening. The same applies much more seriously in the case of transformer couplings, with the addition of a lagging displacement at the lowest frequencies due to the inductance loss. In a number of stages the phase displacement is cumulative. If signals of every frequency were displaced alike there would be no objection; but, as explained above, the effect depends on frequency, so that signals of different frequencies are displaced relative to one another.

The ear is curiously inappreciative of phase distortion, for sustained sounds at least; but the eye cannot so easily tolerate a picture in which the small details have been shifted relative to the larger ones.

Receiver Design.

To get the best results from 30-line television one must exercise a good deal of care in designing an amplifier free from phase distortion up to over 13,000 c./s., but how much more is this true of a 240-line receiver where the video frequency extends up to practically 1,000,000 c./s.!

No attempt can be made to secure a very large gain per stage by using the customary couplings of 50,000 ohms upwards. The coupling resistances are much lower, with a

view to minimizing stray effects. This in itself is not enough; properly calculated inductance coils are connected in series to compensate for capacitance losses. Grid-to-anode capacitances in the valves, which would cause serious interaction between stages, are reduced to small proportions by using screened tetrode or pentode valves. The coupling condensers are abnormally large, to minimize distortion of the very low

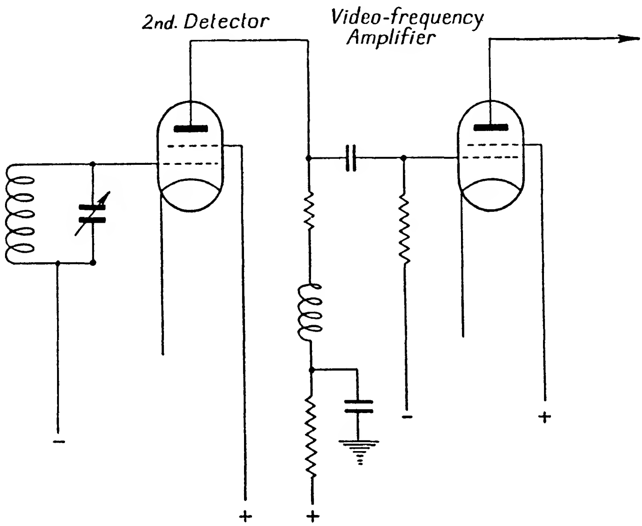


Fig. 16

frequencies corresponding to whole pictures. Decoupling resistors with unusually small by-pass condensers are used as low-frequency boosters to compensate for losses at the 25-cycle end (fig. 16).

As under these conditions only a limited magnification is practicable, a premium is set on those viewing systems that make small power demands.

The precise arrangements for separating and applying the synchronizing signals depend on the type of signal adopted, so full details would not be very helpful at this stage.

Moving backwards from viewer to aerial, we have already seen how the wideness of the video band necessitates a correspondingly wider radio frequency band on which to radiate it, which brings one at once into the ultra-short waves below 10 metres. A wave-length of 6 metres, for instance, is equivalent to 50,000,000 c./s., or 50 megacycles. As the video frequency extends 1 megacycle above and below this, the receiver must respond to a band of frequencies from 49 to 51 megacycles. The aural part of the programme is likely to be transmitted on some fairly adjacent frequency—say 52 megacycles—but of course the band to be accepted is much narrower.

The only type of receiver that fulfils requirements is the superheterodyne; and it is clear that the ordinary intermediate frequency of about 120, or even 465 kc./s., is useless. It must cover a total width of $\pm$ 1000 kc./s. without loss of amplification; so the I.F. itself must be very much higher. On the other hand, the higher it is the more difficult it becomes to get a satisfactory gain per stage of amplification. It seems likely that a frequency of about 6 megacycles (6000 kc./s.) may be standardized.

It is possible to tune in both sound and vision transmissions on a single broadly-tuned aerial, covering (in the example discussed) rather more than 49–52 mc./s. An oscillator working at a frequency of 56 mc./s. is coupled to the whole lot and produces an I.F. vision signal of 5–7 mc./s. and a sound signal of 3·99–4·01 mc./s., which are then amplified separately. The whole scheme is indicated in fig. 17.

The type of aerial commonly used consists of a rod about 10 feet long, connected to the receiver by a special feeder if necessary. But there is scope for greatly improving the results by special types of aerials for those who care to take the trouble to erect them.

Behaviour of Ultra-short Waves.

The results obtainable at these short wave-lengths are strikingly different from those with which listeners are

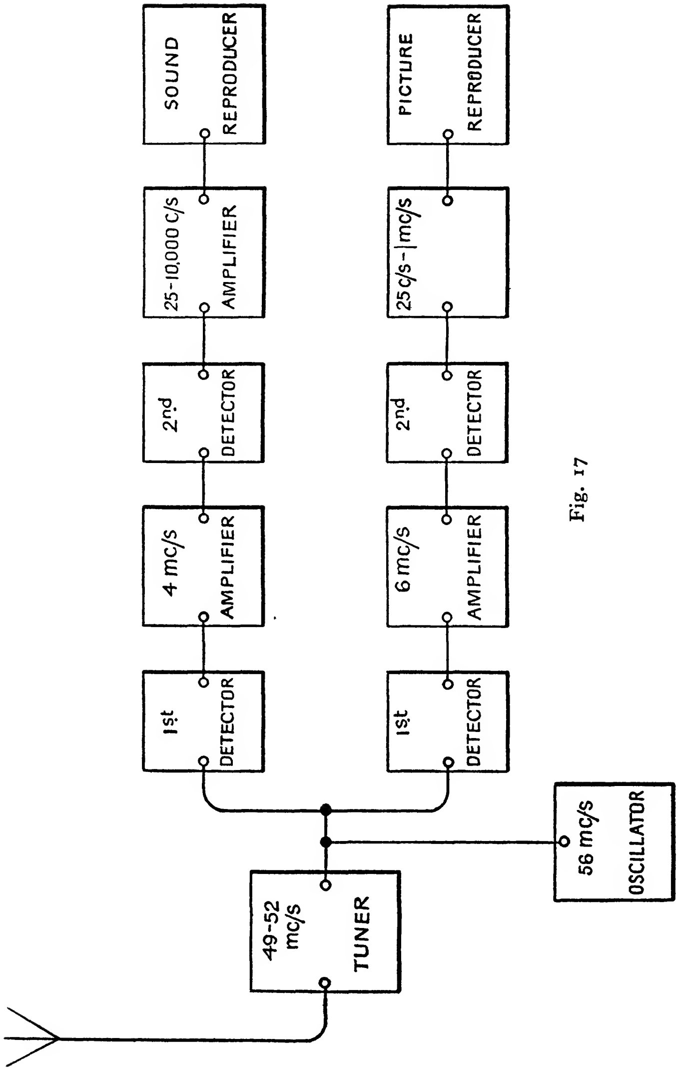

SOUND REPRODUCER
25-10,000 C/S AMPLIFIER
2nd DETECTOR
4 mc/s AMPLIFIER
1st DETECTOR
PICTURE REPRODUCER
25 c/s-1 mc/s
2nd DETECTOR
6 mc/s AMPLIFIER
1st DETECTOR
49-52 mc/s TUNER
56 mc/s OSCILLATOR

Fig. 17

familiar. The long broadcast waves travel for hundreds of miles before becoming too weak to give good reception. The medium waves are more rapidly absorbed along the ground, while at night the range is greatly extended (but often somewhat capriciously) by reflections from upper layers in the atmosphere. The ultra-short waves are still more rapidly absorbed, and no reflection takes place. So the range is very restricted. Moreover, intervening obstructions such as hills or buildings act as screens; and speaking generally one gets satisfactory reception only when there is a clear visible path between transmitter and receiver. For this reason efforts are made to put the transmitting aerial on some high landmark.

Fig. 18 shows approximately the results of some signal strength measurements by the Baird Company with a transmitter at the Crystal Palace in South London. It has been stated that a signal of 1000 microvolts ensures good reception in all normal circumstances; one of 250 microvolts is enough at a distance of over 50 yards from roads bearing motor traffic, and 100 microvolts in situations remote from disturbance. The effects of the configuration of the land are very noticeable, particularly along the North Downs.

Atmospherics are happily unnoticeable and interference from other stations is not a problem (an incidental advantage of the short range), but the ignition systems of petrol engines radiate in this region of wave-length, and may be a major problem when a public service is opened. It might be difficult to compel millions of vehicles to fit suppressing devices.

It is interesting to identify the effects of various types of interference and distortion on the picture reproduction. Irregular interference produces irregular blemishes, while heterodyne whistles, A.C. mains "hum", and other interferences having a definite frequency produce a more or less regular pattern on the picture.

The B.B.C., in their 30-line transmissions, have been in the habit of exhibiting test cards with special geometrical devices for facilitating identification of various forms of receiver

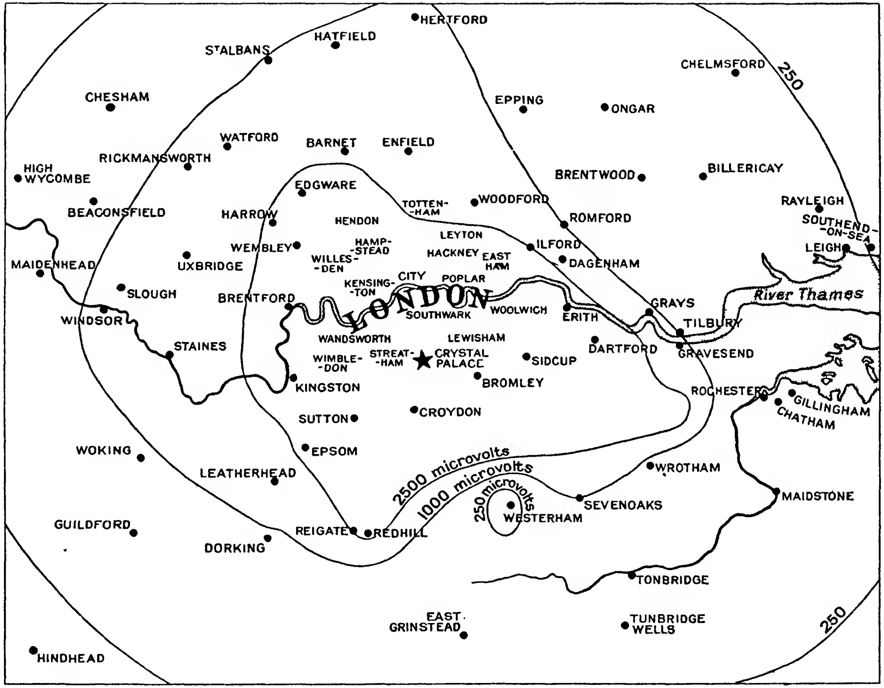

HERTFORD
HATFIELD
STALBANS
CHELMSFORD
250
CHESHAM
EPPING
ONGAR
WATFORD
BARNET
ENFIELD
RICKMANSWORTH
HIGH WYCOMBE
BRENTWOOD
BILLERICAY
EDGWARE
TOTTEN-HAM
WOODFORD
RAYLEIGH
BEACONSFIELD
HARROW
HENDON
ROMFORD
SOUTHEND-ON-SEA
LEYTON
WEMBLEY
HAMP-STEAD
ILFORD
LEIGH
UXBRIDGE
HACKNEY
EAST HAM
DAGENHAM
MAIDENHEAD
WILLES-DEN
KENSING-TON
CITY
POPLAR
SLOUGH
BRENTFORD
LONDON
River Thames
SOUTHWARK
WOOLWICH
GRAYS
WINDSOR
ERITH
TILBURY
STAINES
WANDSWORTH
LEWISHAM
DARTFORD
GRAVESEND
WIMBLE-DON
STREAT-HAM
CRYSTAL PALACE
SIDCUP
KINGSTON
BROMLEY
ROCHESTER
GILLINGHAM
CHATHAM
SUTTON
CROYDON
EPSOM
WOKING
2500 microvolts
1000 microvolts
WROTHAM
LEATHERHEAD
250 microvolts
MAIDSTONE
SEVENOAKS
WESTERHAM
GUILDFORD
REIGATE
REDHILL
DORKING
TONBRIDGE
EAST GRINSTEAD
TUNBRIDGE WELLS
250
HINDHEAD

Fig. 18

distortion; and no doubt something of the sort will form part of the high-definition service.

Another incidental advantage of ultra-short wave-lengths is that the restrictions on the audio frequency band are lifted, so that the sound accompaniments to television programmes may be expected to have a better tonal quality than those radiated on longer waves.

CHAPTER VII

The Programme Service

Distribution.

As the area served by any one television transmitter is so small—about 25 miles radius on the average—it appears that to serve the whole country a large number of transmitters are required, linked by lines for distributing programmes of national interest and for avoiding the prohibitive expense of so many independent programmes. Such a system is much more easily suggested than carried into effect; for it must be remembered that the video signal covers a vastly greater band of frequencies than the audio, including the whole of the long wave broadcast frequencies and most of the medium wave! To transmit such a signal over hundreds of miles of line, without appreciable amplitude or phase distortion, seems quite an impossible proposition. Yet the production of a suitable cable has been claimed; whether the cost of a nation-wide network can be made reasonable is another matter.

An alternative, which although not without its difficulties, seems well within the bounds of possibility, is to join the broadcasting stations by radio links; working perhaps on a still shorter wave-length. So-called microwaves, from one metre downwards, can be focused into narrow beams by means of suitable reflectors, resulting in a sort of radio " search-light "; and communication has been set up experimentally over distances greater than 100 miles. They have been put to regular use across the English Channel and elsewhere. The

cost of such equipment is relatively small, so it may prove more practicable than cable links.

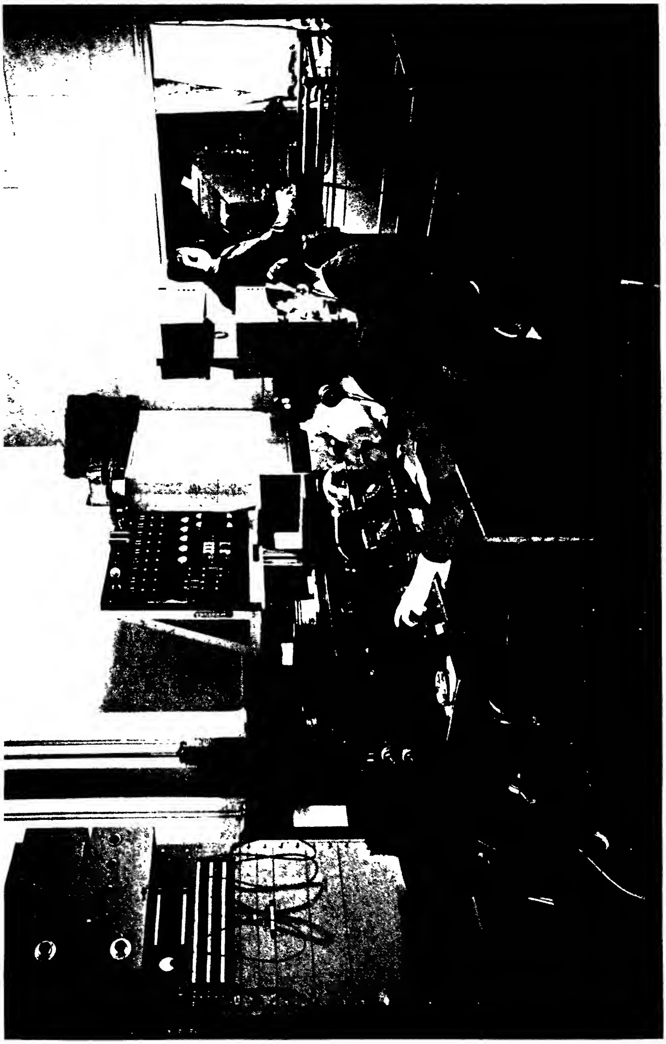
The Programmes.

Turning now to the programmes themselves; is it likely that visual broadcasts will supersede sound alone, just as talking films have superseded the silent movie? Quite apart from the technical difficulties, it would appear not. Demand has obliged broadcasters to provide an almost continuous service of sound from breakfast to midnight. The proportion of time when people are actually devoting the whole of their attention to listening must be quite small. During the morning housewives are listening as they go about their work. Lunch and tea, and perhaps dinner or supper, are carried on over a background of music which has to compete with conversation. Many people who have had a loud speaker running within earshot throughout the day would be unable to give a satisfactory account of what they have heard.

Now although an unheeded background of sound appears to minister to some human need, it is difficult to imagine that an unwatched television screen would do so. Unless it can be given at least the major part of one's attention, it might as well not be on at all. The most inveterate film fan would not wish to gaze at the screen all day, even if the entertainment were free.

Prolonged hours of service would present a problem to the broadcasters also of furnishing a supply of programmes. Only a small proportion of the existing aural programmes would gain substantially by being televized. Vaudeville artists are not likely to be enthusiastic about sterilizing their repertoire in a short time by presenting it everywhere at one performance. Neither are film or theatrical producers.

The greatest field for television is in broadcasting topical or notable events at the time of occurrence, or very shortly after. Unfortunately this is just the most difficult type of



B.B.C. Copyright Photo

B.B.C. 30-line Television Control Room, showing scanner on extreme right

Facing p. 60

programme to reproduce satisfactorily because of the large amount of detail.

There are these and other reasons for believing that for at least a good many years to come vision will be subordinate to sound.

Many of the topical events occur at hours unsuitable for the majority of lookers. The intermediate film process allows the scene to be broadcast at the time (if desired), and later in the News Bulletin, following the procedure adopted by the B.B.C. for sound alone.

The B.B.C. has also developed the art of mixing voices, noise effects, gramophone records, &c., into a composite sound picture; and there is of course plenty of scope for this sort of thing with vision. Already, in the low-definition broadcasts, the studio scene has been mixed with the scanning of a card bearing a title, or even supplementary scenery. The Baird Company provide a still or moving background by projecting it optically on to a back cloth. These and many other tricks of film production are available.

Sundry Applications.

Public broadcasting is not the only field for television. Commercial or police interests may also be served.

For sending messages or news, television offers certain advantages over telegraphy or telephony. Either a whole page may be exhibited at once, or it may be transmitted after the fashion of the moving news strips one sees on building frontages. The latter can be done on quite low-definition systems. It has already been mentioned that television lends itself to code transmission so that either words or pictures can be sent secretly.

Facsimile (transmission of actual handwriting, diagrams, &c.) is commonly sent by picture telegraphy; but where a permanent record is not required (except by photographing the received image) television can do it at much greater speed.

It is quite conceivable that the methods of television may be used to defeat one of the chief remaining dangers at sea (and elsewhere)—fog. In referring to noctovision it was pointed out that visible light is not essential. Infra-red light, which penetrates fog to a very large extent, can be used in conjunction with a photo-cell that is sensitive to radiation of that particular wave-length. It seems likely that some of the recent methods could be adopted for scanning the murky outlook and reproducing it visibly on a screen. Comparatively low definition would show up such objects as adjacent ships, rocks, or icebergs.

The author believes that something of this sort has actually been tried on a motor-car; the windscreen being replaced by a television screen, so that the driver had no direct outlook from the car at all. The Minister of Transport would probably require convincing proof of the efficiency and reliability of such a device before giving it his general approval.

CHAPTER VIII

The Outlook

Present and Future.

An optimistic parallel has often been traced between the progress of sound broadcasting during the last dozen years, and that which still lies largely in front of television. Reception is admittedly crude. But (they say) remember the old crystal set and compare it with a modern superhet.

It seems that too much may be made of this. In the crystal set era of 1922–5, valves, although not in universal use, were present. The superheterodyne was present. In fact, substantially all of the modern technique was present, at least in embryo. What we have now is due to straight-forward development; but it is difficult to see how straight-forward development will make television as nearly perfect *and as adaptable* as modern sound transmission. The standard to be aimed at, as regards definition, depth of tone, flickerlessness, brilliance and size of picture, cheapness and simplicity of operation—leaving aside colour and stereoscopy—is appallingly high.

On the other hand progress already has been rapid and fruitful, and recent developments open up an entrancing vista of future accomplishment. It may almost be considered that the promising lines for exploration are too many: technique must be tolerably stable before it is a good commercial article.

The present time is perhaps the most difficult at which to assess results. Much of the work being done by the leading

research organizations is not released for publication. But enough has appeared to show that it is practicable to broadcast visual programmes and receive them on easily manageable (albeit rather costly) sets, providing definite entertainment value of a standard not far removed from that of " home movies ". Detail improvements will follow as a matter of course at both sending and receiving ends.

The Amateur's Part.

It is here that there is great scope for the amateur. Ordinary radio has been getting too much standardized, too much a factory product. The ground has been surveyed so often by so many that it has lost its thrill for the amateur pioneer. Television offers wide fields that have not yet been trodden down flat. It is not suggested that work such as that of Zworykin and Farnsworth can be done at home. But television combines an unusual number of scientific arts—electrical, mechanical, optical, chemical, photographic—each with many subdivisions, any one of which is a claim that can be staked out.

Amateur cinematographers can try recording received programmes, or methods of scanning film. Simpler and more effective beam deflectors for cathode ray systems are required. Optical systems for projecting pictures form another subject. The radio experimenters who do not want to travel too far off familiar ground can consider reduction of distortion in wide-frequency amplifiers, the " taming " of ultra-short wave receivers, the exclusion of ignition interference, and the evolution of special aerials. One must remember too that the sound programmes on ultra-short waves offer new scope for " high-fidelity " sound reproduction, released from the bondage of high selectivity.

A strong incentive to home experimenters is that not only are complete television sets expensive but that obsolescence is bound to be rapid at first. It was so with broadcasting twelve years ago. People paid exorbitant sums for receivers that suffered about 80 per cent depreciation per annum.

As explained earlier, television is subject to the still greater uncertainty that the receiver is bound to a particular manner of transmission. This seems to be the one really serious stumbling block in the way of television progress.

It must be realized, too, that the construction of an effective high-definition sound-and-vision receiver is not on the same footing as was that of a crystal or even a valve receiver in the early radio days. Complete television is likely to be fairly expensive for some time, however come by; and nothing could be much farther from the truth than the statements put forward in a section of the Press when the Television Report appeared, that ordinary radio was thenceforth obsolete. The change-over, if it is ever accomplished at all, will take many years.

Fortunately for the impecunious experimenter, this does not mean that he has no part or lot in the new inheritance. One can work at aerial systems without going to the expense of vision equipment at all. And so for many other parts of the work.

This small volume can give very little idea of the vast amount that has already been done and is being done. It contains enough, it is hoped, to distinguish the main principles of the subject, and to direct interest aright. Those who want to be first anywhere in the experimental field had better start now.

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